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REPORT

OF THE

SIXTY-EIGHTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

BRISTOL IN SEPTEMBER 1898.

LONDON:
JOHN MURRAY, ALBEMARLE STREET,
1899.

Office of the Association: Burlington House, London, W.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

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[*An asterisk * indicates that the title only is given. The mark † indicates the same, but a reference is given to the journal or newspaper where it is published* in extenso.]

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

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[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee not less than two years in advance[1]; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[3]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[4] and of preparing Reports

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[1] Revised by the General Committee, Liverpool, 1896.

[2] Revised, Montreal, 1884.

[3] Passed, Edinburgh, 1871.

[4] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the Sectional Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee except for Thursday and Saturday.[5]

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880. [3] Edinburgh, 1871.

[4] The meeting on Saturday is optional, Southport, 1883. [5] Nottingham, 1893.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxi), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

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[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.[2]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.

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[1] Revised by the General Committee, Bath, 1888.

[2] Revised by the General Committee at Ipswich, 1895.

5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor G. Carey Foster, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.
7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such report has been received.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of Natural History are requested to reserve the specimens so obtained to be dealt with by authority of the Association.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

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[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee, except for Thursday and Saturday.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[3]

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[1] Passed by the General Committee at Newcastle, 1863.

[2] Passed by the General Committee at Birmingham, 1865.

[3] Passed by the General Committee at Leeds, 1890.

Corresponding Societies.[1]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Assistant General Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to

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[1] Passed by the General Committee, 1884.

the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of[1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of

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[1] Passed by the General Committee at Belfast, 1874.

whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year —observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S, M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Glong, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S. A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbel ,D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.

PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.

SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

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SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire. The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford The Mayor of Oxford Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine. The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.

CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, BART., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire. Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of The Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.

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1895-97 A. G. Vernon Harcourt, Esq., F.R.S., and Prof. E. A. Schäfer, F.R.S.
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MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Date and Place	Presidents	Secretaries
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.......	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.

Date and Place	Presidents	Secretaries
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.

Date and Place	Presidents	Secretaries
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.
1885. Aberdeen	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof W. E. Ayrton, F.R.S.	Prof. A. P. Chattock, J. L. Howard, C. H. Lees, Prof. W. Watson, E. T. Whittaker.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton	Dr. J. H. Gladstone, F.R.S.	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford	Prof. W. J. Russell, F.R.S.	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth	F. A. Abel, F.R.S.	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

Date and Place	Presidents	Secretaries
1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn
1897. Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol......	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

Date and Place	Presidents	Secretaries
1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

Date and Place	Presidents	Secretaries
1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place	Presidents	Secretaries
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.

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[1] Geography was constituted a separate Section, under the title of the 'Geographical and Ethnological Section,' see page lxiv.

Date and Place	Presidents	Secretaries
1867. Dundee ...	Archibald Geikie, F.R.S.	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S., Sec. G.S.	J. Lomas, Prof. H. A. Miers, Clement Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol	W. H. Hudleston, F.R.S.......	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

Date and Place	Presidents	Secretaries
1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

Date and Place	Presidents	Secretaries
1835. Dublin	Dr. Allman	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow	Sir W. J. Hooker, LL.D.	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxiii.]

Date and Place	Presidents	Secretaries
1848. Swansea	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool	Prof. Balfour, M.D., F.R.S.	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

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[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxiii.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham[1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh.	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

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[1] The title of Section D was changed to Biology; and for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' was substituted.

Date and Place	Presidents	Secretaries
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.[1]	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[2]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.

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[1] The Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] Anthropology was made a separate Section, see p. lxx.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath.........	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff......	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol......	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

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[1] Physiology was made a separate Section, see p. lxx.

[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lvii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

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[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lx.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxi.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.
1859. Aberdeen	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton	Francis Galton, F.R.S.	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut.-General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow	Capt. Evans, C.B., F.R.S.	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.

Date and Place	Presidents	Secretaries
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto	J. Scott-Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850 Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. Stark.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines..................	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich....	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves.........	J. G. Fitch, James Meikle.
1872. Brighton...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol......	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin......	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P..........	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.

Date and Place	Presidents	Secretaries
1884. Montreal	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool	Rt. Hon. L. Courtney, M.P.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol	J. Bonar, M.A., LL.D.	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. South'mpt'n	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingh'm	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.

Date and Place	Presidents	Secretaries
1854. Liverpool	John Scott Russell, F.R.S.	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow	W. J. M. Rankine, F.R.S.	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S.	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	William Fairbairn, F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea	J. Abernethy, F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton	John Fowler, C.E., F.G.S.	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	J. Brunlees, Pres. Inst. C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.

Date and Place	Presidents	Secretaries
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.
1898. Bristol	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.

SECTION I.—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).

1894. Oxford	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.

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Date and Place	Presidents	Secretaries
1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
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1898. Bristol......	Prof. F. O. Bower, F.R.S. ...	A. C. Seward, H. Wager, J. W. White.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S............	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.

Date and Place	Lecturer	Subject of Discourse
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ...	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.

Date and Place	Lecturer	Subject of Discourse
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S.........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.........	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.

Date and Place	Lecturer	Subject of Discourse
1894. Oxford……	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich …	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool…	Dr. F. Elgar, F.R.S. …………	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto …	Prof. Roberts Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S………………	Earthquakes and Volcanoes.
1898. Bristol……	Prof. W. J. Sollas, F.R.S. …	Funafuti: the Study of a Coral Island.
	Herbert Jackson ……………	Phosphorescence.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee……	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich …	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter ……	Prof. Miller, M.D., F.R.S. …	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool…	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton …	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford …	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast ……	Prof. Odling, F.R.S…………	The Discovery of Oxygen.
1875. Bristol ……	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow …	Commander Cameron, C.B….	A Journey through Africa.
1877. Plymouth…	W. H. Preece…………………	Telegraphy and the Telephone.
1879. Sheffield …	W. E. Ayrton ………………	Electricity as a Motive Power.
1880. Swansea …	H. Seebohm, F.Z.S. …………	The North-East Passage.
1881. York………	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. …	Talking by Electricity—Telephones.
1884. Montreal …	Prof. R. S. Ball, F.R.S………	Comets.
1885. Aberdeen …	H. B. Dixon, M.A. …………	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S. ……	Electric Lighting.
1888. Bath………	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E. ………	The Forth Bridge.
1890. Leeds ……	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff ……	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes………	Spontaneous Combustion.
1894. Oxford……	Prof. W. J. Sollas, F.R.S. …	Geologies and Deluges.
1895. Ipswich …	Dr. A. H. Fison………………	Colour.
1896. Liverpool…	Prof. J. A. Fleming, F.R.S….	The Earth a Great Magnet.
1897. Toronto …	Dr. H. O. Forbes ……………	New Guinea.
1898. Bristol……	Prof. E. B. Poulton, F.R.S.	The ways in which Animals Warn their enemies and Signal to their friends.

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Gaskell, Dr. W. H., F.R.S.
Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A.
Herdman, Professor W. A., F.R.S.
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Thomson, Professor J. M., F.R.S.
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The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Sir John Lubbock, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Professor A. W. Rücker, M.A., D.Sc., Sec. R.S.

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Prof. J. S. Burdon Sanderson, F.R.S.
The Marquis of Salisbury, K.G., F.R.S.
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Sir John Evans, K.C.B., F.R.S.

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Prof. A. W. Williamson, F.R.S.
Sir Douglas Galton, K.C.B., F.R.S.
A. Vernon Harcourt, Esq., F.R.S.
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AUDITORS.

Dr. J. H. Gladstone, F.R.S.
Dr. D. H. Scott, F.R.S.
Sir H. Trueman Wood, M.A.

Dr.

THE GENERAL TREASURER'S ACCOUNT,

1897–98.

RECEIPTS.

	£	s.	d.
Balance brought forward	2396	0	4
Life Compositions	120	0	0
New Annual Members' Subscriptions	218	0	0
Annual Subscriptions	465	0	0
Members of American Association	159	0	0
Sale of Associates' Tickets	648	0	0
Sale of Ladies' Tickets	103	0	0
Sale of Publications	175	17	0
Interest on Deposit at Liverpool Bank	24	5	6
Dividend on Consols	200	7	4
Dividend on India 3 per Cents	104	8	0
Unexpended Balance of Grant returned by the Committee for the Calculation of certain Integrals	10	0	0
	£4623	18	2

Investments.

	£	s.	d.
Consols	7537	3	5
India 3 per Cents	3600	0	0
	£11,137	3	5

ARTHUR W RÜCKER, *General Treasurer.*

from July 1, 1897, to June 30, 1898. *Cr.*

1897–98. EXPENDITURE.

	£	s.	d.	£	s.	d.
Expenses of Toronto Meeting, including Printing, Advertising, Payment of Clerks, &c.				108	9	7
Rent and Office Expenses				60	16	0
Salaries				510	0	0
Printing, Binding, &c.				1028	8	7
Payment of Grants made at Toronto:						
Electrical Standards	75	0	0			
Seismological Observations	75	0	0			
Abstracts of Physical Papers	100	0	0			
Calculation of certain Integrals	10	0	0			
Electrolysis and Electro-chemistry	35	0	0			
Meteorological Observatory at Montreal	50	0	0			
Wave-length Tables of the Spectra of the Elements	20	0	0			
Action of Light upon Dyed Colours	8	0	0			
Erratic Blocks	5	0	0			
Investigation of a Coral Reef	40	0	0			
Photographs of Geological Interest	10	0	0			
Life-zones in British Carboniferous Rocks	15	0	0			
Pleistocene Fauna and Flora in Canada	20	0	0			
Table at the Zoological Station, Naples	100	0	0			
Table at the Biological Laboratory, Plymouth	14	0	0			
Index Generum et Specierum Animalium	100	0	0			
Healthy and Unhealthy Oysters	30	0	0			
Climatology of Tropical Africa	10	0	0			
State Monopolies in other Countries	15	0	0			
Small Screw Gauge	20	0	0			
North-Western Tribes of Canada	75	0	0			
Lake Village at Glastonbury	37	10	0			
Silchester Excavation	7	10	0			
Ethnological Survey of Canada	75	0	0			
Anthropology and Natural History of Torres Strait	125	0	0			
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0			
Fertilisation in Phæophyceæ	15	0	0			
Corresponding Societies Committee	25	0	0			
				1212	0	0
In hands of General Treasurer:						
On deposit at Liverpool (National Provincial Bank)	1521	2	7			
At Bank of England, Western Branch £219 11 1						
Less Cheque not presented 37 10 0	182	1	1			
				1703	3	8
Petty Cash in hand				1	0	4
				£4623	18	2

I have examined the above Account with the books and vouchers of the Association, and certify the same to be correct. I have also verified the balances at the bankers on Current and Deposit Accounts, and have ascertained that the Investments are duly registered in the names of the Trustees.

W. B. Keen, *Chartered Accountant,*
3 Church Court, Old Jewry, E.C.
July 12, 1898.

Approved—
Herbert McLeod, } *Auditors.*
D. H. Scott }

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents		
			Old Life Members	New Life Members
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, DD.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Asso-ciates	Ladies	Foreigners	Total			
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

REPORT OF THE COUNCIL.

Report of the Council for the Year 1897–98, *presented to the General Committee at Bristol on Wednesday, September* 7, 1898.

The Meeting held at Toronto last August was attended by a representative body of members from the British Isles and from the Dominion of Canada, and by a large number of scientific men from the United States of America and from the Continent of Europe. The success of the Meeting had been confidently anticipated in view of the experience of the Montreal Meeting in 1884, and that this anticipation was fully realised was largely the result of the unremitting exertions of the Local Officers and Committee at Toronto, and the support which was received from the Government of the Dominion, the Government of Ontario, and the City of Toronto.

A Permanent Committee on Terrestrial Magnetism and Atmospheric Electricity was appointed at the Meeting of the International Meteorological Conference at Paris in 1896. The members of this body were desirous of holding a Conference with other magneticians, and at the suggestion of Professor Rücker, who is President of the Committee, the Council decided to invite the Committee to hold the Conference at Bristol during the Meeting of the British Association. This invitation was accepted, and it was decided that the Conference should meet as a Department of Section A, and that the foreign magneticians who might attend should have all the privileges of foreign members of the Association. The Council have reason to believe that this arrangement will work satisfactorily, and that the Conference will be well attended.

The Council have nominated the Master of the Society of Merchant Venturers to be a Vice-President of the Association for the Meeting at Bristol, in addition to the Vice-Presidents elected at the last meeting of the General Committee.

The Council have received Reports from the General Treasurer during the past year, and his Accounts from July 1, 1897, to June 30, 1898, which have been audited, will be presented to the General Committee.

The Council have been informed by Professor Rücker that he does not intend to offer himself for re-election as General Treasurer after the Bristol Meeting. Professor Rücker has held this post since 1891, and the Council desire to put on record their sense of the important services which Professor Rücker has rendered to the Association during this period. The Council recommend that Professor G. Carey Foster, F.R.S., be appointed General Treasurer in succession to Professor Rücker.

The Council have to deplore the loss by death of Lord Playfair, who had been one of the Trustees of the Association since 1883. The Council have nominated Professor Rücker as Trustee, the other Trustees being Lord Rayleigh and Sir John Lubbock.

The Council have elected the following men of Science who have attended Meetings of the Association to be Corresponding Members:—

Professor C. Barus, Brown University.
M. C. de Candolle, Geneva.
Dr. G. W. Hill, West Nyack, N.Y.
Professor Oskar Montelius, Stockholm.
Professor E. W. Morley, Cleveland, Ohio.
Professor C. Richet, Paris.
Professor W. B. Scott, Princeton, N.J.

The Council were invited to nominate one or two Members to give evidence before the Committee appointed by the Government to report on the desirability of establishing a National Physical Laboratory, and at their request Professor G. Carey Foster, F.R.S., and Professor W. E. Ayrton, F.R.S., gave evidence before this Committee. A Report has been presented to Parliament, and the Council trust that the deliberations of the Committee will result in the establishment of a National Laboratory.

In regard to the Resolutions referred to them for consideration and action, if desirable, the Council have to report:—

(1) That the Council appointed a Committee to consider the desirability of approaching the Government with a view to the establishment in Britain of experimental Agricultural Stations similar in character to those which are producing such satisfactory results in Canada. The Committee having reported that much is already being done in this direction by County Councils and Agricultural Societies, advised that the co-operation of these bodies should first be invited. The Committee was re-appointed for this purpose, and sent in a Report, the principal recommendation of which was adopted by the Council, and is as follows:

'Your Committee recommend that the Board of Agriculture be informed that, in the opinion of the British Association, there is an urgent need for the co-ordination of existing institutions for agricultural research, and that the Association hopes that steps may be taken towards this end, including the strengthening of the scientific work of the Board of Agriculture and the provision of the means for dealing adequately with scientific questions which may come before it.'

At the request of the Council this Report was brought by the President to the notice of the President of the Board of Agriculture, from whom the following reply was received:—

Board of Agriculture,
4 Whitehall Place, London, S.W., 26th July, 1898.

SIR,—I have laid before the Board of Agriculture your letter of the 18th inst., and I am desired to express to the Council of the British Association for the Advancement of Science the thanks of the Board for the attention which the Council have been so good as to give to the important subject of agricultural research.

The Board will not fail to bear in mind the views set out in the Resolution communicated to them in the letter above referred to.

I am, Sir, your obedient servant,
P. G. CRAIGIE, Assistant Secretary.

Sir John Evans, K.C.B., F.R.S., &c., President of the British Association for the Advancement of Science, Burlington House, W.

(2) That a Committee was appointed to report to the Council whether, and, if so, in what form, it is desirable to bring before the Canadian Government the necessity for a Hydrographic Survey of Canada, and that the following formed the Committee:—Professor A. Johnson (Chairman and Secretary), Lord Kelvin, Professor G. H. Darwin, Admiral Sir W. J. L. Wharton, Professor Bovey, and Professor Macgregor.

The Committee reported to the Council, and it was decided, in conformity with the recommendation contained in the Report, that the following Resolution should be sent to the Canadian Government:—

'The Council of the British Association have learnt with regret that the Government of the Dominion of Canada is contemplating the discontinuance of their Tidal Survey of Canadian Waters. Whilst the work already carried out is primarily connected with Hydrography and Navigation, they consider that Science will incur a great loss if the work of the Survey is discontinued. They would, therefore, urge on the Government the desirability of continuing the Tidal Survey as heretofore.'

The President transmitted the Resolution to the Governor-General, who forwarded it to the Government of the Dominion of Canada for their favourable consideration.

The Council have received the following in reply :—

Extract from a Report of the Committee of the Honourable the Privy Council, approved by His Excellency on the 20th June, 1898.

On a Report dated 25th April, 1898, from the Minister of Marine and Fisheries, stating that he has had under consideration a letter, dated 9th March, 1898, from the President of the British Association for the Advancement of Science, enclosing a resolution adopted at a meeting of the Council of the Association, urging the desirability of continuing the Tidal Survey as heretofore.

The Minister recommends that the Association be informed that, in view of the limited appropriation made by Parliament, it has been deemed advisable to defer the prosecution of the Survey for the present, and to confine the work to the maintenance and operations of the Tidal gauges already established, and the preparation of tide tables.

The Committee submit the same for your Excellency's approval.

JOHN J. MCGEE,
Clerk of the Privy Council.

(3) That a Committee was appointed by the Council to consider the following Resolution : 'That, in view of the facts (*a*) that a Committee of Astronomers appointed by the Royal Society of London, in consequence of a communication from the Royal Society of Canada, has recently considered the matter, and has arrived at the conclusion that no change can now be introduced in the "Nautical Almanac" for 1901, and (*b*) that few English astronomers are attending the Toronto meeting of the Association : the Committees of Sections A and E are not in a position to arrive at any definite conclusions with respect to the Unification of Time ; but they think it desirable to call the attention of the Council to the subject, in which the interests of mariners are deeply involved, with the view of their taking such action in the matter as may seem to them to be desirable.'

Several members of this Committee had also served on the Committee of the Royal Society, and after careful re-consideration of the whole question the Committee saw no good reason for dissenting from the conclusion which had been recently adopted by the Royal Society, and reported in the following terms :—

'The Committee report that, as there is a great diversity of opinion amongst astronomers and sailors as to the desirability of the adoption of civil reckoning for astronomical purposes, and as it is impossible to carry out such a change in the "Nautical Almanac" for the year 1901, they do not recommend that the Council of the British Association should at present take any steps in support of the suggested change of reckoning.'

The President has transmitted this Report to the Royal Society of Canada.

In their Report last year at Toronto the Council informed the General Committee that the establishment of a Bureau for Ethnology was under the consideration of the Trustees of the British Museum. Since that date, the following letter, addressed to the President, has been received :

British Museum, December 15, 1897.

Dear Sir John Evans,—Referring to a letter of May 19 last, from Lord Lister, as President of the British Association for the Advancement of Science, requesting the Trustees of the British Museum to consider whether they could allow a Bureau for

Ethnology for Greater Britain to be established in connection with the Museum, I am directed by the Trustees to inform you that they are quite of opinion that such a Bureau might be administered in connection with the Ethnographical Section of their collections with advantage both to the objects in view of the Association and to the enlargement of the British Museum collections. They are, therefore, willing to accept in principle the proposal of the British Association, and they would be ready to take the necessary steps for carrying it into effect so soon as certain re-arrangements affecting space, &c., which are now taking place within the Museum, shall have been finished, as it is expected, in the course of the coming year.

Believe me, yours very truly,
E. MAUNDE THOMPSON.

Sir John Evans, K.C.B., D.C.L., LL.D., &c. &c.

The Report of the Corresponding Societies Committee for the past year, together with the list of the Corresponding Societies and the titles of the more important papers, and especially those referring to Local Scientific Investigations, published by those Societies during the year ending June 1, 1898, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola (*Chairman*), Sir Douglas Galton, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Professor T. G. Bonney, Mr. T. V. Holmes, Sir Cuthbert E. Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, and Professor W. W. Watts, is hereby nominated for reappointment by the General Committee.

The Council nominate Mr. W. Whitaker, F.R.S., Chairman, and Mr. T. V. Holmes, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Bristol.

The Council announce with very great regret the loss that they have recently sustained by the death of Dr. John Hopkinson, F.R.S.

In accordance with the regulations the retiring Members of the Council will be :—

Edgeworth, Professor.
Horsley, Mr. Victor.
Symons, Mr. G. J.
Ramsay, Professor W.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Boys, C. Vernon, Esq., F.R.S.
Creak, Captain E. W., R.N., F.R.S.
Darwin, F., Esq., F.R.S.
Fremantle, The Hon. Sir C. W., K.C.B.
*Gaskell, Dr. W. H., F.R.S.
Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A., M.Inst.C.E.
Herdman, Professor W. A., F.R.S.
*Keltie, J. Scott, Esq., LL.D.
*MacMahon, Major P. A., F.R.S.
Marr, J. E., Esq., F.R.S.
Meldola, Professor R., F.R.S.
Poulton, Professor E. B., F.R.S.
Preece, W. H., Esq., C.B., F.R.S.
*Price, L. L., Esq., M.A.
Reynolds, Professor J. Emerson, M.D., F.R.S.
Shaw, W. N., Esq., F.R.S.
Teall, J. J. H., Esq., F.R.S.
Thiselton-Dyer, W. T., Esq., C.M.G., F.R.S.
Thompson, Professor S. P., F.R.S.
Thomson, Professor J. M., F.R.S.
*Tilden, Professor W. A., F.R.S.
Tylor, Professor E. B., F.R.S.
Unwin, Professor W. C., F.R.S.
White, Sir W. H., K.C.B., F.R.S.

An invitation to hold the Annual Meeting of the Association in the year 1900 at Bradford, and an invitation from Cork for a future Meeting, have been received, and will be presented to the General Committee on Monday, September 12.

COMMITTEES APPOINTED BY THE GENERAL COMMITTEE AT THE BRISTOL MEETING IN SEPTEMBER 1898.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [And 75*l.*, last year's grant not expended.]	*Chairman.*—Lord Rayleigh. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, Oliver J. Lodge, and G. Carey Foster, Dr. A. Muirhead, Mr. W. H. Preece, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Mr. E. H. Griffiths, Professor A. W. Rücker, and Professor H. L. Callendar.	225 0 0
Seismological Observations.	*Chairman.*—Prof. J. W. Judd. *Secretary.*—Professor J. Milne. Lord Kelvin, Sir F. J. Bramwell, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Professor C. G. Knott, Professor R. Meldola, Professor J. Perry, Professor J. H. Poynting, Professor T. G. Bonney, Mr. C. V. Boys, Professor H. H. Turner, Mr. G. J. Symons, and Dr. C. Davison.	75 0 0
To assist the publication of 'Science Abstracts.'	*Chairman.*—Professor A. W. Rücker. *Secretary.*—Professor W. E. Ayrton. Captain Abney and Professor S. P. Thompson.	100 0 0
Experiments on the Heat of combination of Metals in the formation of Alloys.	*Chairman.*—Lord Kelvin. *Secretary.*—Dr. A. Galt. Professor F. G. FitzGerald, Dr. J. H. Gladstone, and Professor O. J. Lodge.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
Radiation from a source of Light in a Magnetic Field.	*Chairman.*—Professor G. F. Fitzgerald. *Secretary.*—Professor T. Preston. Professor A. Schuster, Professor O. J. Lodge, Professor S. P. Thompson, Professor Molloy, and Professor W. E. Adeney.	50 0 0
To co-operate with Professor Karl Pearson in the Calculation of certain Integrals.	*Chairman.*—Rev. Robert Harley. *Secretary.*—Dr. A. R. Forsyth. Dr. J. W. L. Glaisher, Professor A. Lodge, and Professor Karl Pearson.	10 0 0
The Action of Light upon Dyed Colours.	*Chairman.*—Dr. T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. W. H. Perkin, Professor W. J. Russell, Captain Abney, Professor W. Stroud, and Professor R. Meldola.	10 0 0
The relation between the Absorption Spectra and Chemical Constitution of Organic Substances.	*Chairman* and *Secretary.*—Professor W. Noel Hartley. Professor F. R. Japp, and Professor J. J. Dobbie.	50 0 0
To establish a Uniform System of recording the Results of the Chemical and Bacterial Examination of Water and Sewage.	*Chairman.*—Professor W. Ramsay. *Secretary.*—Dr. S. Rideal. Sir W. Crookes, Professor F. Clowes, Professor P. F. Frankland, and Professor R. Boyce.	10 0 0
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Prof. P. F. Kendall. Professor T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. J. Horne, Mr. Dugald Bell, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, and Mr. R. D. Tucker.	15 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, R. H. Tiddeman, J. J. H. Teall, J. G. Goodchild, H. Coates, and C. V. Crook.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Mr. E. J. Garwood. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Dr. Wheelton Hind, Dr. G. J. Hinde, Mr. P. F. Kendall, Mr. J. W. Kirkley, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. G. H. Morton, Professor H. A. Nicholson, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	10 0 0
To examine the Conditions under which remains of the Irish Elk are found in the Isle of Man.	*Chairman.*—Professor W. Boyd Dawkins. *Secretary.*—Mr. P. C. Kermode. His Honour Deemster Gill, Mr. G. W. Lamplugh, and Canon E. B. Savage.	15 0 0
To further investigate the Fauna and Flora of the Pleistocene Beds in Canada.	*Chairman.*—Sir J. W. Dawson. *Secretary.*—Professor A. P. Coleman. Professor D. P. Penhallow, Dr. H. Ami, and Mr. G. W. Lamplugh.	30 0 0
Photographic and other Records of the Disappearing Drift Section at Moel Tryfaen.	*Chairman.*—Dr. H. Hicks. *Secretary.*—Mr. E. Greenly. Mr. A. Strahan, Professor P. Kendall, Professor J. F. Blake, Mr. T. Mellard Reade, and Mr. G. H. Morton.	5 0 0
The Investigation of the Ty Newydd Caves, Tremeirchion.	*Chairman.*—Dr. H. Hicks. *Secretary.*—Rev. G. C. H. Pollen. Mr. A. Strahan, Mr. E. T. Newton, Mr. G. H. Morton, and Rev. — Hull.	40 0 0
The Excavation of the Ossiferous Caves at Uphill, near Weston-super-Mare.	*Chairman.*—Professor C. Lloyd Morgan. *Secretary.*—Mr. H. Bolton. Professor W. Boyd Dawkins, Mr. W. R. Barker, Mr. Reynolds, and Mr. E. T. Newton.	30 0 0
To enable Dr. H. Lyster Jamieson, or, failing him, some other competent investigator, to carry on a definite piece of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor G. B. Howes. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, and Professor W. C. M'Intosh.	100 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To enable Mr. Martin T. Woodward to study the embryology of the Mollusca; Mr. T. N. Taylor to investigate the embryology of the Polyzoa; and Mr. G. Brebner to continue his studies on the reproduction of marine Algæ, and to enable other competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman.*—Mr. G. C. Bourne. *Secretary.* — Professor E. Ray Lankester. Professor Sydney H. Vines, Mr. A. Sedgwick, Professor W. F. R. Weldon, and Mr. W. Garstang.	20 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. R. McLachlan, and Mr. W. E. Hoyle.	100 0 0
To work out the details of the Observations on the Migration of Birds at Lighthouses and Lightships, 1880–87.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Rev. E. P. Knubley, and Dr. H. O. Forbes.	15 0 0
To construct a Circulatory Apparatus for keeping Aquatic Organisms under definite Physical Conditions.	*Chairman.*—Mr. W. E. Hoyle. *Secretary.*—Mr. F. W. Gamble. Professor S. J. Hickson and Mr. F. W. Keeble.	15 0 0
The Periodic Investigation of the Plankton and Physical Conditions of the English Channel during 1899.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Mr. Walter Garstang. Professor W. A. Herdman, and Mr. H. N. Dickson.	100 0 0
The Exploration of the Island Socotra.	*Chairman.*—Dr. J. Scott Keltie. *Secretary.*—Dr. H. O. Forbes, Dr. W. T. Blanford, Professor Bayley Balfour, Professor W. F. R. Weldon.	35 0 0
State Monopolies in other Countries. [Unexpended balance of 13*l.* 13*s.* 6*d.*]	*Chairman.*—Professor H. Sidgwick. *Secretary.*—Mr. H. Higgs. Mr. W. M. Acworth, the Rt. Hon. L. H. Courtney, and Professor H. S. Foxwell.	—
Future dealings in Raw Produce.	*Chairman.*—Mr. L. L. Price. *Secretary.*—Prof. A. W. Flux. Major P. G. Craigie, Professor W. Cunningham, Professor Edgeworth, Professor Gonner, Mr. R. H. Hooker, and Mr. H. R. Rathbone.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To consider means by which better practical effect can be given to the Introduction of the Screw Gauge proposed by the Association in 1884. [Balance of last year's grant unexpended, 17*l.* 1*s.* 2*d.*]	*Chairman.*—Mr. W. H. Preece. *Secretary.*—Mr. W. A. Price. Lord Kelvin, Sir F. J. Bramwell, Sir H. Trueman Wood, Maj.-Gen. Webber, Mr. R. E. Crompton, Mr. A. Stroh, Mr. A. Le Neve Foster, Mr. C. J. Hewitt, Mr. G. K. B. Elphinstone, Mr. T. Buckney, Col. Watkin, Mr. E. Rigg, Mr. Conrad W. Cooke, and Mr. Vernon Boys.	—
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, Sir John Evans, and Mr. Arthur J. Evans.	50 0 0
To organise an Ethnographical Survey of the United Kingdom. [And unexpended balance in hand, 11*l.*]	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. E. Sidney Hartland. Mr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Mr. W. Crooke, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur J. Evans, Dr. H. O. Forbes, Mr. F. G. Hilton Price, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, and Mr. E. G. Ravenstein.	25 0 0
To co-operate with the Silchester Excavation Fund Committee in their Explorations	*Chairman.*—Mr. A. J. Evans. *Secretary.*—Mr. John L. Myres. Mr. E. W. Brabrook.	10 0 0
To organise an Ethnological Survey of Canada.	*Chairman.*—Professor D. P. Penhallow. *Secretary.*—Dr. George Dawson. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Sir J. G. Bourinot, Abbé Cuoq, Mr. B. Sulte, Abbé Tanquay, Mr. C. Hill-Tout, Mr. David Boyle, Rev. Dr. Scadding, Rev. Dr. J. Maclean, Dr. Merée Beauchemin, Rev. Dr. G. Patterson, Mr. C. N. Bell, Professor E. B. Tylor, Hon. G. W. Ross, Professor J. Mavor, and Mr. A. F. Hunter.	35 0 0
Preparing a new edition of 'Notes and Queries on Anthropology.'	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Dr. J. G. Garson. General Pitt-Rivers, Mr. C. H. Read and Mr. J. L. Myres.	40 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To conduct Explorations with the object of ascertaining the age of Stone Circles.	*Chairman.*—Dr. J. G. Garson. *Secretary.*—Mr. H. Balfour. Gen. Pitt-Rivers, Sir John Evans, Mr. C. H. Read, Professor Meldola, Mr. A. J. Evans, Dr. R. Munro, and Professor Boyd-Dawkins.	20 0 0
The physiological effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.* — Professor E. A. Schäfer. *Secretary.* — Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.	30 0 0
Investigation of the Electrical Changes accompanying the Discharge of the Respiratory Centres.	*Chairman.*—Dr. A. Waller. *Secretary.*—Professor Waymouth Reid. Professor F. Gotch and Dr. J. S. McDonald.	20 0 0
Influence of Drugs upon the Vascular Nervous System.	*Chairman.*—Professor Francis Gotch. *Secretary.*—Professor W. D. Halliburton. Dr. F. W. Mott.	10 0 0
Histological Changes in Nerve-cells.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor R. Boyce. Professor C. S. Sherrington and Dr. W. B. Warrington.	20 0 0
The Micro-chemistry of Cells.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor A. B. Macallum. Professor E. Ray Lankester, Professor W. D. Halliburton, and Mr. G. C. Bourne.	40 0 0
Histology of Suprarenal Capsules.	*Chairman.*—Professor E. A. Schäfer. *Secretary*—Mr. Swale Vincent. Mr. Victor Horsley.	20 0 0
Comparative Histology of Cerebral Cortex.	*Chairman.*—Professor F. Gotch. *Secretary.*—Dr. G. Mann. Dr. F. W. Mott.	10 0 0
Fertilisation in Phæophyceæ.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. W. Phillips. Professor F. O. Bower and Professor Harvey Gibson.	20 0 0
Experimental Investigation of Assimilation in Plants.	*Chairman.*—Mr. F. Darwin. *Secretary.*—Professor J. R. Green. Professor Marshall Ward.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Zoological and Botanical Publication.	*Chairman.*—Rev. T. R. R. Stebbing. *Secretary.*—Mr. F. A. Bather. Professor W. A. Herdman, Professor W. F. R. Weldon, Mr. A. C. Seward, Mr. Adam Sedgwick, Mr. C. D. Sherborn, Mr. B. Daydon Jackson, Mr. W. E. Hoyle, Dr. P. L. Sclater, and Dr. D. Sharp.	5 0 0
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Sir Cuthbert E. Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, and Professor W. W. Watts.	25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
To confer with British and Foreign Societies publishing Mathematical and Physical Papers as to the desirability of securing Uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman.*—Professor S. P. Thompson. *Secretary.*—Mr. J. Swinburne. Prof. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Professor A. W. Rücker, and Dr. G. Johnstone Stoney.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray, Dr. A. Buchan, and Professor R. Copeland.
To confer with the Astronomer Royal and the Superintendents of other Observatories with reference to the Comparison of Magnetic Standards with a view of carrying out such comparison.	*Chairman.*—Professor A. W. Rücker. *Secretary.*—Professor W. Watson. Professor A. Schuster and Professor H. H. Turner.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The present state of our Knowledge in Electrolysis and Electro-chemistry.	*Chairman.*—Mr. W. N. Shaw. *Secretary.*—Mr. W. C. D. Whetham. Rev. T. C. Fitzpatrick, Mr. E. H. Griffiths, and Mr. S. Skinner.
To establish a Meteorological Observatory on Mount Royal, Montreal.	*Chairman.*—Professor H. L. Callendar. *Secretary.*—Professor C. H. McLeod. Professor F. Adams and Mr. R. F. Stupart.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Professor Edward Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Professor Michie Smith, and Professor H. L. Callendar.
That Professor S. P. Thompson and Professor A. W. Rücker be requested to draw up a Report on the State of our Knowledge concerning Resultant Tones.	—
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola, Mr. John Hopkinson, and Mr. H. N. Dickson.
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.	*Chairman.*—Lord Kelvin. *Secretary.*—Lieut.-Colonel Allan Cunningham. Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. Macmahon, and Professor A. Lodge.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Dr. G. Johnstone Stoney. *Secretary.*—Professor H. McLeod. Sir G. G. Stokes, Professor A. Schuster, Sir H. E. Roscoe, Captain W. de W. Abney, Dr. C. Chree, Professor G. F. FitzGerald, Professor H. L. Callendar, Mr. G. J. Symons, Mr. W. E. Wilson, and Professor A. A. Rambaut.
To consider the most suitable Method of Determining the Components of the Magnetic Force on board Ship.	*Chairman.*—Professor A. W. Rücker. *Secretary.*—Mr. C. H. Lees. Lord Kelvin, Professor A. Schuster, Captain Creak, Professor Stroud, Mr. C. V. Boys, and Mr. W. Watson.
That Mr. E. T. Whittaker be requested to draw up a Report on the Planetary Theory.	—

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
That Miss Hardcastle be requested to draw up a Report on the present state of the Theory of Point-Groups.	—
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. George Gladstone, Mr. W. R. Dunstan, Sir J. Lubbock, Sir Philip Magnus, Sir H. E. Roscoe, Dr. Silvanus P. Thompson, and Professor A. Smithells.
The Electrolytic Methods of Quantitative Analysis.	*Chairman.*—Professor J. Emerson Reynolds. *Secretary.*—Dr. C. A. Kohn. Professor Frankland, Professor F. Clowes, Dr. Hugh Marshall, Mr. A. E. Fletcher, and Professor W. Carleton Williams.
The Promotion of Agriculture: to report on the means by which in various Countries Agriculture is advanced by research, by special Educational Institutions, and by the dissemination of information and advice among Agriculturists.	*Chairman.*—Sir John Evans. *Secretary.*—Professor H. E. Armstrong. Professor M. Foster, Professor Marshall Ward, Sir J. H. Gilbert, Right Hon. J. Bryce, Professor J. W. Robertson, Dr. W. Saunders, Professor Mills, Professor J. Mavor, Professor R. Warington, Professor Poulton, and Mr. S. U. Pickering.
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Professor T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Professor H. G. Seeley, and Mr. H. Woods.
The Collection, Preservation, and Systematic Registration of Canadian Photographs of Geological Interest.	*Chairman.*—Professor A. P. Coleman. *Secretary.*—Mr. Parks. Professor A. B. Willmott, Professor F. D. Adams, Mr. J. B. Tyrrell, and Professor W. W. Watts.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To report upon the present state of our Knowledge of the Structure of Crystals.	*Chairman.*—Professor N. Story Maskelyne. *Secretary.*—Professor H. A. Miers. Mr. L. Fletcher, Professor W. J. Sollas, Mr. W. Barlow, Mr. G. F. H. Smith, and the Earl of Berkeley.
To continue the investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Dr. A. C. Günther, Dr. D. Sharp, Mr. F. Du Cane Godman, and Professor A. Newton.
To promote the Systematic Collection of Photographic and other Records of Pedigree Stock.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Professor W. F. R. Weldon.
Climatology of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Mr. H. N. Dickson. Sir John Kirk, Dr. H. R. Mill, and Mr. G. J. Symons.
To Investigate and Report on Professor Elisée Reclus' Scheme of producing a Relief Globe on a large scale.	*Chairman.*—Col. G. Earl Church. *Secretary.*—Mr. E. G. Ravenstein. Lieut.-Col. F. Bailey, Professor P. Geddes, Dr. J. Scott Keltie, and Dr. H. R. Mill.
The Anthropology and Natural History of Torres Straits.	*Chairman.*—Sir W. Turner. *Secretary.*—Professor A. C. Haddon. Professor M. Foster, Dr. J. Scott Keltie, Professor L. C. Miall, and Professor Marshall Ward.
To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the investigation of the Mental and Physical Condition of Children.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. E. W. Brabrook, Dr. J. G. Garson, and Mr. White Wallis.
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. J. L. Myres. Dr. J. G. Garson, Mr. H. Ling Roth, Mr. H. Balfour, Mr. E. S. Hartland, and Professor Flinders Petrie.
The Present State of Anthropological Teaching in the United Kingdom and Elsewhere.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. H. Ling Roth. Professor A. Macalister, Professor A. C. Haddon, Mr. C. H. Read, Mr. H. Balfour, Mr. F. W. Rudler, Dr. R. Munro, and Professor Flinders Petrie.

Communications ordered to be printed in extenso.

'On Logarithmic Coordinates,' by Dr. J. H. Vincent.

'On Stream-Line Motion with Viscous Fluids in Two Dimensions,' by Professor H. S. Hele-Shaw.

'Mathematical Proof of the Identity of the Stream-Lines obtained by Means of a Viscous Film with those of a Perfect Fluid moving in Two Dimensions,' by Professor Sir G. G. Stokes, F.R.S.

'On the Relative Advantages of Long and Short Magnets,' by Professor E. Mascart.

'On the Establishment of Temporary Magnetic Observatories in certain localities, especially in Tropical Countries,' by Professor von Bezold and Gen.-Major Rykatcheff.

'Photographic Records of Pedigree Stock,' with the accompanying Illustrations, by Mr. Francis Galton.

'Some of the Mechanical and Economic Features of the Coal Question,' by Mr. T. Forster Brown.

'A new Instrument for drawing Envelopes, and its Application to the Teeth of Wheels, and for other purposes,' by Professor H. S. Hele-Shaw.

'The Papers on the Alternation of Generations in the Archegoniatæ and Thallophyta,' by Professor Klebs and Mr. W. H. Lang, in the Proceedings of the Sections.

Resolutions referred to the Council for consideration, and action if desirable.

That having regard to the letter of December 15 last, from Sir E. Maunde Thompson, the Council be requested to take further action with regard to a Bureau of Ethnology, by renewing the correspondence with the Trustees of the British Museum.

That the Council be requested to consider the desirability of representing to the Colonial Government that the early establishment of a Magnetic Observatory at the Cape of Good Hope would be of the highest utility to the science of Terrestrial Magnetism, especially in view of the Antarctic Expeditions which are about to leave Europe, and that the Observatory should be established at such a distance from electric railways and tramways as to avoid all possibility of disturbance from them.

That the Council be requested to consider the advisability of urging Her Majesty's Government to place at the disposal of the Seismological Committee of the British Association a suitable building for the housing of Apparatus for continuous Seismological observations.

That the Council be requested to urge strongly on the Indian Government the desirability, in the interests both of administration and of science, to promote an inquiry, under the direction of skilled anthropologists, into the physical and mental characteristics of the various races throughout the Empire, including their institutions, customs, and traditions, and a carefully organised photographic survey.

That the Council be recommended to issue the collected Reports on the North-Western Tribes of Canada in a single volume at a moderate price, reprinting so many of the Reports as may be necessary.

That the Council be requested to bring under the notice of the Admiralty the importance of securing systematic observations upon the Erosion of the sea coast of the United Kingdom, and that the co-operation of the Coastguard might be profitably secured for this purpose.

That the Council be requested to take into consideration whether any alterations in the hours of meeting of the Sectional Committees and of the General Committee on the first day of the Annual Meeting of the Association are desirable, and to report to the General Committee at the Dover meeting.

Change of Days of Meeting of General Committee and Committee of Recommendations.

The second meeting of the General Committee was appointed to be held on Friday, and the first meeting of the Committee of Recommendations on the following Monday.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Bristol Meeting, September, 1898. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics.

	£	s.	d.
*Rayleigh, Lord—Electrical Standards (and £75 in hand) ...	225	0	0
*Judd, Professor J. W.—Seismological Observations	75	0	0
*Rücker, Professor A. W.—'Science Abstracts'	100	0	0
Kelvin, Lord—Heat of Combination of Metals	20	0	0
FitzGerald, Professor G. F.—Radiation in a Magnetic Field	50	0	0
*Harley, Rev. R.—Calculation of Certain Integrals	10	0	0

Chemistry.

	£	s.	d.
*Thorpe, Dr. T. E.—Action of Light upon Dyed Colours	10	0	0
Hartley, Professor W. N.—Relation between Absorption Spectra and Constitution of Organic Substances	50	0	0
Ramsay, Professor W.—Chemical and Bacterial Examination of Water and Sewage	10	0	0

Geology.

	£	s.	d.
*Hull, Professor E.—Erratic Blocks	15	0	0
*Geikie, Professor J.—Photographs of Geological Interest ...	10	0	0
*Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks	10	0	0
*Dawkins, Professor Boyd.—Remains of Irish Elk in the Isle of Man	15	0	0
*Dawson, Sir J. W.—Pleistocene Fauna and Flora in Canada	30	0	0
Hicks, Dr. H.—Records of Drift Section at Moel Tryfaen...	5	0	0
Hicks, Dr. H.—Ty Newydd Caves	40	0	0
Lloyd-Morgan, Professor C.—Ossiferous Caves at Uphill ...	30	0	0

Zoology.

	£	s.	d.
*Herdman, Professor W. A.—Table at the Zoological Station, Naples	100	0	0
*Bourne, Mr. G. C.—Table at the Biological Laboratory, Plymouth	20	0	0
*Woodward, Dr. H.—Index Generum et Specierum Animalium	100	0	0
*Newton, Professor A.—Migration of Birds	15	0	0
Hoyle, Mr. W. E.—Apparatus for keeping Aquatic Organisms under definite Physical Conditions	15	0	0
Lankester, Professor E. R.—Plankton and Physical Conditions of the English Channel during 1899	100	0	0

Geography.

	£	s.	d.
Keltie, Dr. J. Scott—Exploration of Socotra	35	0	0
Carried forward	1,090	0	0

* Reappointed.

	£	s.	d.
Brought forward	1,090	0	0
Economic Science and Statistics.			
*Sidgwick, Professor H.—State Monopolies in other Countries (£13 13*s.* 6*d.* in hand)	—		
*Price, Mr. L. L.—Future Dealings in Raw Produce	5	0	0
Mechanical Science.			
*Preece, Mr. W. H.—Small Screw Gauge (£17 1*s.* 2*d.* in hand)	—		
Anthropology.			
*Munro, Dr. R.—Lake Village at Glastonbury	50	0	0
*Brabrook, Mr. E. W.—Ethnographical Survey (and balance in hand)	25	0	0
*Evans, Mr. A. J.—Silchester Excavation	10	0	0
*Penhallow, Professor D. P.—Ethnological Survey of Canada (and £35 17*s.* 0*d.* in hand)	35	0	0
Tylor, Professor E. B.—New Edition of 'Anthropological Notes and Queries'	40	0	0
Garson, Dr. J. G.—Age of Stone Circles	20	0	0
Physiology.			
*Schäfer, Professor E. A.—Physiological Effects of Peptone	30	0	0
Waller, Dr. A.—Electrical Changes accompanying Discharge of Respiratory Centres	20	0	0
Gotch, Professor F.—Influence of Drugs upon the Vascular Nervous System	10	0	0
Schäfer, Professor E. A.—Histological Changes in Nerve Cells	20	0	0
Schäfer, Professor E. A.—Micro-chemistry of Cells	40	0	0
Schäfer, Professor E. A.—Histology of Suprarenal Capsules	20	0	0
Gotch, Professor F.—Comparative Histology of Cerebral Cortex	10	0	0
Botany.			
*Farmer, Professor J. B.—Fertilisation in Phæophyceæ	20	0	0
Darwin, Mr. F.—Assimilation in Plants	20	0	0
*Stebbing, Rev. T. R. R.—Zoological and Botanical Publication	5	0	0
Corresponding Societies.			
*Meldola, Professor R.—Preparation of Report	25	0	0
	£1,495	0	0

* Reappointed.

The Annual Meeting in 1899.

The Annual Meeting of the Association in 1899 will commence on Wednesday, September 13, at Dover.

The Annual Meeting in 1900.

The Annual Meeting of the Association in 1900 will be held at Bradford.

The Annual Meeting in 1901.

The Annual Meeting of the Association in 1901 will be held at Glasgow.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854.........£ 75 0 0 1855.........£500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860......£50 0 0 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee..............	64	13	4
Balloon Committee	50	0	0
Metrical Committee..........	50	0	0
British Rainfall.................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards...........	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania...........	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall.................	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards...........	100	0	0
Ethyl and Methyl Series......	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture...	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee...........	50	0	0
Zoological Record..............	100	0	0
Kent's Hole Explorations ...	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors.............	50	0	0
Organic Acids	60	0	0
Fossil Crustacea................	25	0	0
Methyl Series.....................	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee.................	50	0	0
Metrical Committee..............	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deepwell Water	25	0	0
British Rainfall..................	50	0	0
Thermal Conductivity of Iron, &c..............................	30	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron......................	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series....................	30	0	0
Organic Remains in Limestone Rocks.......................	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature ...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards............	25	0	0
High Insulation Key............	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record..............	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements..............	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record..............	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters..........................	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise..............	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives..........................	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax......	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters..........................	15	0	0
Geological Record..............	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station...	25	0	0
Elimination of Nitrogen by Bodily Exercise..............	38	3	3
Exploration of Mount Kilima-njaro...................... .	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges......................	5	0	0
	£1083	3	3

1884.

Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust..................	20	0	0
Meteorological Observatory at Chepstow.......................	25	0	0
Tidal Observations..............	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa.....................	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters..........................	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds..............	20	0	0
Coagulation of Blood...........	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

Electrical Standards...........	25	0	0
Photographs of Meteorological Phenomena..............	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills............................	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave.....	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart...........	10	0	0
Exploration in Abyssinia ...	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics............................	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury............................	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children...............	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards...........	25	0	0
Photographs of Meteorological Phenomena.....................	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives..........................	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills.....	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea........... .	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut ...	50	0	0
Calibration and Comparison of Measuring Instruments ...	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph........	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours	8	0	0
Erratic Blocks	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest	10	0	0
Life-zones in British Carboniferous Rocks..................	15	0	0
Pleistocene Fauna and Flora in Canada	20	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	14	0	0
Index Generum et Specierum Animalium	100	0	0
Healthy and Unhealthy Oysters	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries	15	0	0
Small Screw Gauge	20	0	0
North-Western Tribes of Canada........	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee	25	0	0
	£1,212	0	0

General Meetings.

On Wednesday, September 7, at 8 P.M., in the People's Palace, Bristol, Sir John Evans, K.C.B., D.C.L., LL.D., resigned the office of President to Sir William Crookes, F.R.S., V.P.C.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 8, at 8.30 P.M., a Soirée took place in the Clifton College.

On Friday, September 9, at 8.30 P.M., in the People's Palace, Professor W. J. Sollas, M.A., F.R.S., delivered a discourse on 'Funafuti: the Study of a Coral Island.'

On Monday, September 12, at 8.30 P.M., in the People's Palace, Herbert Jackson, Esq., delivered a discourse on 'Phosphorescence.'

On Tuesday, September 13, at 8.30 P.M., a Soirée took place in the Clifton College.

On Wednesday, September 14, at 2.30 P.M., in the Museum, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Dover. [The Meeting is appointed to commence on Wednesday, September 13, 1899.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR WILLIAM CROOKES, F.R.S., V.P.C.S.

PRESIDENT.

For the third time in its history the British Association meets in your City of Bristol. The first meeting was held under the presidency of the Marquis of Lansdowne in 1836, the second under the presidency of Sir John Hawkshaw in 1875. Formerly the President unrolled to the meeting a panorama of the year's progress in physical and biological sciences. To-day the President usually restricts himself to specialities connected with his own work or deals with questions which for the time are uppermost. To be President of the British Association is undoubtedly a great honour. It is also a great opportunity and a great responsibility; for I know that, on the wings of the Press, my words, be they worthy or not, will be carried to all points of the compass. I propose first to deal with the important question of the supply of bread to the inhabitants of these Islands, then to touch on subjects to which my life work has been more or less devoted. I shall not attempt any general survey of the sciences; these, so far as the progress in them demands attention, will be more fitly brought before you in the different Sections, either in the Addresses of the Presidents or in communications from Members.

Before proceeding with my address I wish to refer to the severe loss the British Association has sustained in the death of Lord Playfair. With Sir John Lubbock and Lord Rayleigh, Lord Playfair was one of the Permanent Trustees of our Association, and for many years he was present at our meetings. It would be difficult to overrate his loss to British science. Lord Playfair's well-matured and accurate judgment, his scientific knowledge, and his happy gift of clothing weighty thoughts in persuasive language, made his presence acceptable, whether in the council chamber, in departmental enquiries, or at light social gatherings, where by the singular laws of modern society, momentous announcements are sometimes first given to the world. Lord Playfair (then Sir Lyon

Playfair) was President of the British Association at Aberdeen in 1885; his Address on that occasion will long be remembered as a model of profound learning and luminous exposition.

And now I owe a sort of apology to this brilliant audience. I must ask you to bear with me for ten minutes, for I am afraid what I now have to say will prove somewhat dull. I ought to propitiate you, for, to tell the truth, I am bound to bore you with figures. Statistics are rarely attractive to a listening audience; but they are necessary evils, and those of this evening are unusually doleful. Nevertheless, when we have proceeded a little way on our journey I hope you will see that the river of figures is not hopelessly dreary. The stream leads into an almost unexplored region, and to the right and left we see channels opening out, all worthy of exploration, and promising a rich reward to the statistic explorer who will trace them to their source—a harvest, as Huxley expresses it, 'immediately convertible into those things which the most sordidly practical of men will admit to have value, namely, money and life.' My chief subject is of interest to the whole world—to every race—to every human being It is of urgent importance to-day, and it is a life and death question for generations to come. I mean the question of Food supply. Many of my statements you may think are of the alarmist order; certainly they are depressing, but they are founded on stubborn facts. They show that England and all civilised nations stand in deadly peril of not having enough to eat. As mouths multiply, food resources dwindle. Land is a limited quantity, and the land that will grow wheat is absolutely dependent on difficult and capricious natural phenomena. I am constrained to show that our wheat-producing soil is totally unequal to the strain put upon it. After wearying you with a survey of the universal dearth to be expected, I hope to point a way out of the colossal dilemma. It is the chemist who must come to the rescue of the threatened communities. It is through the laboratory that starvation may ultimately be turned into plenty.

The food supply of the kingdom is of peculiar interest to this meeting, considering that the grain trade has always been, and still is, an important feature in the imports of Bristol. The imports of grain to this city amount to about 25,000,000 bushels per annum—8,000,000 of which consist of wheat.

What are our home requirements in the way of wheat? The consumption of wheat per head of the population (unit consumption) is over 6 bushels per annum; and taking the population at 40,000,000, we require no less than 240,000,000 bushels of wheat, increasing annually by 2,000,000 bushels, to supply the increase of population. Of the total amount of wheat consumed in the United Kingdom we grow 25 and import 75 per cent.

So important is the question of wheat supply that it has attracted the attention of Parliament, and the question of national granaries has been mooted. It is certain that, in case of war with any of the Great Powers, wheat would be contraband, as if it were cannon or powder, liable to capture even under a neutral flag. We must therefore accept the situation and treat wheat as munitions of war, and grow, accumulate, or store it as such. It has been shown that at the best our stock of wheat and flour amounts only to 64,000,000 bushels—fourteen weeks' supply—while last April our stock was equal to only 10,000,000 bushels, the smallest ever recorded by 'Beerbohm' for the period of the season. Similarly, the stocks held in Europe, the United States, and Canada, called 'the world's visible supply,' amounted to only 54,000,000 bushels, or 10,000,000 less than last year's sum total, and nearly 82,000,000 less than that of 1893 or 1894 at the corresponding period. To arrest this impending danger, it has been proposed that an amount of 64,000,000 bushels of wheat should be purchased by the State and stored in national granaries, not to be opened, except to remedy deterioration of grain, or in view of national disaster rendering starvation imminent. This 64,000,000 bushels would add another fourteen weeks' life to the population; assuming that the ordinary stock had not been drawn on, the wheat in the country would only then be enough to feed the population for twenty-eight weeks.

I do not venture to speak authoritatively on national granaries. The subject has been discussed in the daily press, and the recently published Report from the Agricultural Committee on National Wheat Stores brings together all the arguments in favour of this important scheme, together with the difficulties to be faced if it be carried out with necessary completeness.

More hopeful, although difficult and costly, would be the alternative of growing most, if not all our own wheat supply here at home in the British Isles. The average yield over the United Kingdom last year was 29·07 bushels per acre, the average for the last eleven years being 29·46. For twelve months we need 240,000,000 bushels of wheat, requiring about 8,250,000 acres of good wheat-growing land, or nearly 13,000 square miles, increasing at the rate of 100 square miles per annum, to render us self-supporting as to bread food. This area is about one-fourth the size of England.[1]

A total area of land in the United Kingdom equal to a plot 110 miles square, of quality and climate sufficient to grow wheat to the extent of 29 bushels per acre, does not seem a hopeless demand.[2] It is doubtful, however, if this amount of land could be kept under wheat, and the necessary expense of high farming faced, except under the imperious pressure of impending starvation, or the stimulus of a national subsidy or permanent high prices. Certainly these 13,000 square miles would not be available under ordinary economic conditions, for much, perhaps all, the land now under barley and oats would not be

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[1] Appendix A.

[2] The total area of the United Kingdom is 120,979 square miles; therefore the required land is about a tenth part of the total.

suitable for wheat. In any case, owing to our cold, damp climate and capricious weather, the wheat crop is hazardous, and for the present our annual deficit of 180,000,000 bushels must be imported. A permanently higher price for wheat is, I fear, a calamity that ere long must be faced. At enhanced prices, land now under wheat will be better farmed, and therefore will yield better, thus giving increased production without increased area.

The burning question of to-day is, What can the United Kingdom do to be reasonably safe from starvation in presence of two successive failures of the world's wheat harvest, or against a hostile combination of European nations? We eagerly spend millions to protect our coasts and commerce; and millions more on ships, explosives, guns, and men; but we omit to take necessary precautions to supply ourselves with the very first and supremely important munition of war—food.

To take up the question of food-supply in its scientific aspect, I must not confine myself exclusively to our own national requirements. The problem is not restricted to the British Isles—the bread-eaters of the whole world share the perilous prospect—and I do not think it out of place if on this occasion I ask you to take with me a wide, general survey of the wheat supply of the whole world.

Wheat is the most sustaining food grain of the great Caucasian race, which includes the peoples of Europe, United States, British America, the white inhabitants of South Africa, Australasia, parts of South America, and the white population of the European colonies. Of late years the individual consumption of wheat has almost universally increased. In Scandinavia it has risen 100 per cent. in twenty-five years; in Austro-Hungary, 80 per cent.; in France, 20 per cent.; while in Belgium it has increased 50 per cent. Only in Russia and Italy, and possibly Turkey, has the consumption of wheat per head declined.

In 1871 the bread-eaters of the world numbered 371,000,000. In 1881 the numbers rose to 416,000,000; in 1891, to 472,600,000, and at the present time they number 516,500,000. The augmentation of the world's bread-eating population in a geometrical ratio is evidenced by the fact that the yearly aggregates grow progressively larger. In the early seventies they rose 4,300,000 per annum, while in the eighties they increased by more than 6,000,000 per annum, necessitating annual additions to the bread supply nearly one-half greater than sufficed twenty-five years ago.

How much wheat will be required to supply all these hungry mouths with bread? At the present moment it is not possible to get accurate estimates of this year's wheat crops of the world, but an adequate idea may be gained from the realised crops of some countries and the promise of others. To supply 516,500,000 bread-eaters, if each bread-eating unit is to have his usual ration, will require a total of 2,324,000,000 bushels for seed and food. What are our prospects of obtaining this amount?

According to the best authorities the total supplies from the 1897-98 harvest are 1,921,000,000 bushels.[1] The requirement of the 516,500,000 bread-eaters for seed and food are 2,324,000,000 bushels ; there is thus a deficit of 403,000,000 bushels, which has not been urgently apparent owing to a surplus of 300,000,000 bushels carried over from the last harvest. Respecting the prospects of the harvest year just beginning it must be borne in mind that there are no remainders to bring over from last harvest. We start with a deficit of 103,000,000 bushels and have 6,500,000 more mouths to feed. It follows, therefore, that one-sixth of the required bread will be lacking unless larger drafts than now seem possible can be made upon early produce from the next harvest.[2]

The majority of the wheat crops between 1882 and 1896 were in excess of current needs, and thus considerable reserves of wheat were available for supplementing small deficits from the four deficient harvests. But bread-eaters have almost eaten up the reserves of wheat, and the 1897 harvest being under average, the conditions become serious.[3] That scarcity and high prices have not prevailed in recent years is due to the fact that since 1889 we have had seven world crops of wheat and six of rye abundantly in excess of the average. These generous crops increased accumulations to such an extent as to obscure the fact that the harvests of 1895 and 1896 were each much below current requirements. Practically speaking, reserves are now exhausted, and bread-eaters must be fed from current harvests—accumulation under present conditions being almost impossible. This is obvious from the fact that a harvest equal to that of 1894 (the greatest crop on record, both in acre-yield and in the aggregate) would yield less than current needs.[4]

It is clear we are confronted with a colossal problem that must tax the wits of the wisest. When the bread-eaters have exhausted all possible supplies from the 1897–98 harvest, there will be a deficit of 103,000,000 bushels of wheat, with no substitution possible unless Europeans can be induced to eat Indian corn or rye bread. Up to recent years the growth of wheat has kept pace with demands. As wheat-eaters increased, the acreage under wheat expanded. The world has become so familiarised with the orderly sequence of demand and supply, so accustomed to look upon the vast plains of other wheat-growing countries as inexhaustible granaries, that, in a light-hearted way it is taken for granted that so many million additional acres can be added year after year to the wheat-growing area of the world. We forget that the wheat-growing area is of strictly limited extent, and that a few million acres regularly absorbed, soon mount to a formidable number.

The present position being so gloomy, let us consider future prospects. What are the capabilities as regards available area, economic conditions, and acreage yield of the wheat-growing countries from whence we now draw our supply ?

[1] Appendix B.

[2] Appendix C.

[3] Appendix D.

[4] Apppendix E.

For the last thirty years the United States have been the dominant factor in the foreign supply of wheat, exporting no less than 145,000,000 bushels. This shows how the bread-eating world has depended, and still depends, on the United States for the means of subsistence. The entire world's contributions to the food-bearing area have averaged but 4,000,000 acres yearly since 1869. It is scarcely possible that such an average, under existing conditions, can be doubled for the coming twenty-five years.[1] Almost yearly, since 1885, additions to the wheat-growing area have diminished, while the requirements of the increasing population of the States have advanced, so that the needed American supplies have been drawn from the acreage hitherto used for exportation. Practically there remains no uncultivated prairie land in the United States suitable for wheat-growing. The virgin land has been rapidly absorbed, until at present there is no land left for wheat without reducing the area for maize, hay, and other necessary crops.[2]

It is almost certain that within a generation the ever increasing population of the United States will consume all the wheat grown within its borders, and will be driven to import, and, like ourselves, will scramble for a lion's share of the wheat crop of the world. This being the outlook, exports of wheat from the United States are only of present interest, and will gradually diminish to a vanishing point. The inquiry may be restricted to such countries as probably will continue to feed bread-eaters who annually derive a considerable part of their wheat from extraneous sources.

But if the United States, which grow about one-fifth of the world's wheat, and contribute one-third of all wheat exportations, are even now dropping out of the race, and likely soon to enter the list of wheat-importing countries, what prospect is there that other wheat-growing countries will be able to fill the gap, and by enlarging their acreage under wheat, replace the supply which the States have so long contributed to the world's food? The withdrawal of 145 million bushels will cause a serious gap in the food supply of wheat importing countries, and unless this deficit can be met by increased supplies from other countries there will be a dearth for the rest of the world after the British Isles are sufficiently supplied.

Next to the United States, Russia is the greatest wheat exporter, supplying nearly 95 million bushels.[3]

Although Russia at present exports so lavishly this excess is merely provisional and precarious. The Russian peasant population increases more rapidly than any other in Europe. The yield per acre over European Russia is meagre—not more than 8·6 bushels to the acre—while some authorities consider it as low as 4·6 bushels. The cost of production is low—lower even than on the virgin soils of the United States. The development of the fertile though somewhat overrated

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[1] Appendix F. [2] Appendix G. [3] Appendix H.

'black earth,' which extends across the southern portion of the empire and beyond the Ural Mountains into Siberia, progresses rapidly. But, as we have indicated, the consumption of bread in Russia has been reduced to danger point. The peasants starve and fall victims to 'hunger typhus,' whilst the wheat growers export grain that ought to be consumed at home.

Considering Siberia as a wheat grower, climate is the first consideration. Summers are short—as they are in all regions with continental climates north of the 45th parallel—and the ripening of wheat requires a temperature averaging at least 65° Fahr. for fifty-five to sixty-five days. As all Siberia lies north of the summer isotherm of 65° it follows that such region is ill adapted to wheat culture unless some compensating climatic condition exists. As a fact, the conditions are exceptionally unfavourable in all but very limited districts in the two westernmost governments. The cultivable lands of Western Siberia adapted to grain-bearing neither equal in extent nor in potential productive powers those of Iowa, Minnesota, and Nebraska. There are limited tracts of fair productiveness in Central Siberia and in the valleys of the southern affluents of the Amoor, but these are only just capable of supporting a meagre population.

Prince Hilkoff, Russian Minister of Ways and Communications, declared in 1896 that 'Siberia never had produced, and never would produce, wheat and rye enough to feed the Siberian population.' And, a year later, Prince Krapotkin backed the statement as substantially correct.

Those who attended the meeting of the British Association last year in Canada must have been struck with the extent and marvellous capacity of the fertile plains of Manitoba and the North-West Provinces. Here were to be seen 1,290,000 acres of fine wheat-growing land yielding 18,261,950 bushels, one-fifth of which comes to hungry England. Expectations have been cherished that the Canadian North-West would easily supply the world with wheat, and exaggerated estimates are drawn as to the amount of surplus land on which wheat can be grown.[1] Thus far performance has lagged behind promise, the wheat-bearing area of all Canada having increased less than 500,000 acres since 1884, while the exports have not increased in greater proportion. As the wheat area of Manitoba and the North-West has increased the wheat area of Ontario and the Eastern provinces has decreased, the added acres being little more than sufficient to meet the growing requirements of population. We have seen calculations showing that Canada contains 500,000,000 acres of profitable wheat land. The impossibility of such an estimate ever being fulfilled will be apparent when it is remembered that the whole area employed in both temperate zones for growing all the staple food crops is not more than 580,000,000 acres, and that in no country has more than 9 per cent. of the area been devoted to wheat culture.[2]

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[1] Appendix I.

[2] Appendix J.

The fertility of the North-West Provinces of the Dominion is due to an exceptional and curious circumstance. In winter the ground freezes to a considerable depth. Wheat is sown in the spring, generally April, when the frozen ground has been thawed to a depth of three inches. Under the hot sun of the short summer the grain sprouts with surprising rapidity, partly because the roots are supplied with water from the thawing depths. The summer is too short to thaw the ground thoroughly, and gate-posts or other dead wood extracted in autumn are found still frozen at their lower ends.

Australasia as a potential contributor to the world's supply of wheat affords another fertile field for speculation. Climatic conditions limit the Australian wheat area to a small portion of the southern littoral belt. Professor Shelton considers there are still fifty million acres in Queensland suitable for wheat, but hitherto it has never had more than 150,000 acres under cultivation. Crops in former days were liable to rust, but since the Rust in Wheat conferences and the dissemination of instruction to farmers, rust no longer has any terrors. I am informed by the Queensland Department of Agriculture that of late years they practically have bred wheat vigorous enough to resist this plague. For the second season in succession, the wheat crop last year was destroyed over large areas in Victoria ; and in South Australia the harvest averaged not more than about $3\frac{3}{4}$ bushels per acre after meeting Colonial requirements for food and seed, leaving only 684,000 bushels for export. In most other districts the yield falls to such an extent as to cause Europeans to wonder why the pursuit of wheat-raising is continued.

New Zealand has a moist climate resembling that of central and southern England, while South Australia is semi-arid, resembling western Kansas. Only two countries in the world yield as much wheat per acre as New Zealand—these are Denmark and the United Kingdom. Notwithstanding the great yield of wheat, due to an equable climate, New Zealand finds fruit and dairy farming still more profitable. The climatic conditions favourable to wheat are also conducive to luxuriant growths of nutritious grasses. Thus the New Zealander ships his butter more than half-way round the world, and competes successfully with Western Europe.

During the last twenty-seven years the Austro-Hungarian population has increased 21·8 per cent., as against an increase of 54·6 per cent. in the acreage of wheat. Notwithstanding this disparity in the rates of increase, exports have practically ceased by reason of an advance of nearly 80 per cent. in unit consumption. There can be little doubt that Austro-Hungary is about to enter the ranks of importing nations, although in Hungary a considerable area of wheat land remains to be brought under cultivation.[1]

Roumania is an important wheat-growing country. In 1896 it pro-

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[1] Appendix K.

duced 69,000,000 bushels, and exported 34,000,000 bushels. It has a considerable amount of surplus land which can be used for wheat, although for many years the wheat area is not likely to exceed home requirements.

France comes next to the United States as a producer of wheat; but for our purpose she counts but little, being dependent on supplies from abroad for an average quantity of 14 per cent. of her own production. There is practically no spare land in France that can be put under wheat in sufficient quantity to enable her to do more than provide for increase of population.

Germany is a gigantic importer of wheat, her imports rising 700 per cent. in the last twenty-five years, and now averaging 35,000,000 bushels. Other nations of Europe, also importers, do not require detailed mention, as under no conceivable conditions would they be able to do more than supply wheat for the increasing requirements of their local population, and, instead of replenishing, would probably diminish, the world's stores.

The prospective supply of wheat from Argentina and Uruguay has been greatly overrated. The agricultural area includes less than 100,000,000 acres of good, bad, and indifferent land, much of which is best adapted for pastoral purposes. There is no prospect of Argentina ever being able to devote more than 30,000,000 acres to wheat; the present wheat area is about 6,000,000 acres, an area that may be doubled in the next twelve years. But the whole arable region is subject to great climatic vicissitudes, and to frosts that ravage the fields south of the 37th parallel. Years of systematised energy are frustrated in a few days—perhaps hours—by a single cruelty of Nature, such as a plague of locusts, a tropical rain, or a devastating hail storm. It will take years to bring the surplus lands of Argentina into cultivation, and the population is even now insufficient to supply labour at seed time and harvest.

During the next twelve years, Uruguay may add a million acres to the world's wheat fields; but social, political, and economic conditions seriously interfere with agricultural development.

At the present time South Africa is an importer of wheat, and the regions suitable to cereals do not exceed a few million acres. Great expectations have been formed as to the fertility of Mashonaland, the Shiré Highlands, and the Kikuyu plateau, and as to the adaptation of these regions to the growth of wheat. But wheat culture fails where the banana ripens, and the banana flourishes throughout Central Africa, except in limited areas of great elevation. In many parts of Africa insect pests render it impossible to store grain, and without grain-stores there can be little hope of large exports.

North Africa, formerly the granary of Rome, now exports less than 5,000,000 bushels of wheat annually, and these exports are on the decline, owing to increased home demands. With scientific irrigation, Egypt could supply three times her present amount of wheat, although no increase is likely unless the cotton fields of the Delta are diverted to grain growing. In Algeria and Tunis nearly all reclaimed lands are devoted to the production of wine, for which a brisk demand exists. Were this land devoted to the growth of wheat, an additional five million bushels might be obtained.

The enormous acreage devoted to wheat in India has been declining for some years, and in 1895 over 20,000,000 acres yielded 185,000,000 bushels. Seven-eighths of this harvest is required for native consumption. and only one-eighth on an average is available for export. The annual increase of population is more than 3,000,000, demanding an addition to the food-bearing lands of not less than 1,800,000 acres annually. In recent years the increase has been less than one-fourth of this amount.[1]

In surveying the limitations and vicissitudes of wheat crops, I have endeavoured to keep free from exaggeration, and have avoided insistance on doubtful points. I have done my best to get trustworthy facts and figures, but from the nature of the case it is impossible to attain complete accuracy. Great caution is required in sifting the numerous varying current statements respecting the estimated areas and total produce of wheat throughout the world. The more closely official estimates are examined, the more defective are they found, and comparatively few figures are sufficiently well established to bear the deductions often drawn. In doubtful cases I have applied to the highest authorities in each country, and in the case of conflicting accounts have taken data the least favourable to sensational or panic-engendering statements. In a few instances of accurate statistics their value is impaired by age; but for 95 per cent. of my figures I quote good authorities, while for the remaining 5 per cent. I rely on the best commercial estimates derived from the appearance of the growing crops, the acreage under cultivation, and the yield last year. The maximum probable error would make no appreciable difference in my argument.

The facts and figures I have set before you are easily interpreted. Since 1871 unit consumption of wheat, including seed, has slowly increased in the United Kingdom to the present amount of 6 bushels per head per annum; while the rate of consumption for seed and food by the whole world of bread-eaters was 4·15 bushels per unit per annum for the eight years ending 1878, and at the present time is 4·5 bushels. Under present conditions of low acre yield, wheat cannot long retain its dominant position among the food-stuffs of the civilised world. The details of the impending catastrophe no one can predict, but its general direction is obvious enough. Should all the wheat-growing countries add to their area to the utmost capacity, on the most careful calculation the yield would give us only an addition of some 100,000,000 acres, supplying at the average world-yield of 12·7 bushels to the acre, 1,270,000,000 bushels,

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[1] Appendix L.

just enough to supply the increase of population among bread-eaters till the year 1931.[1]

At the present time there exists a deficit in the wheat area of 31,000 square miles—a deficit masked by the fact that the ten world crops of wheat harvested in the ten years ending 1896 were more than 5 per cent. above the average of the previous twenty-six years.

When provision shall have been made, if possible, to feed 230,000,000 units likely to be added to the bread-eating populations by 1931—by the complete occupancy of the arable areas of the temperate zone now partially occupied—where can be grown the additional 330,000,000 bushels of wheat required ten years later by a hungry world? What is to happen if the present rate of population be maintained, and if arable areas of sufficient extent cannot be adapted and made contributory to the subsistence of so great a host?

Are we to go hungry and to know the trial of scarcity? That is the poignant question. Thirty years is but a day in the life of a nation. Those present who may attend the meeting of the British Association thirty years hence will judge how far my forecasts are justified.

If bread fails—not only us, but all the bread-eaters of the world—what are we to do? We are born wheat-eaters. Other races, vastly superior to us in numbers, but differing widely in material and intellectual progress, are eaters of Indian corn, rice, millet, and other grains; but none of these grains have the food value, the concentrated health-sustaining power of wheat, and it is on this account that the accumulated experience of civilised mankind has set wheat apart as the fit and proper food for the development of muscle and brains.

It is said that when other wheat-exporting countries realise that the States can no longer keep pace with the demand, these countries will extend their area of cultivation, and struggle to keep up the supply *pari passu* with the falling off in other quarters. But will this comfortable and cherished doctrine bear the test of examination?

Cheap production of wheat depends on a variety of causes, varying greatly in different countries. Taking the cost of producing a given quantity of wheat in the United Kingdom at 100*s*., the cost for the same amount in the United States is 67*s*., in India 66s., and in Russia 54*s*. We require cheap labour, fertile soil, easy transportation to market, low taxation and rent, and no export or import duties. Labour will rise in price, and fertility diminish as the requisite manurial constituents in the virgin soil become exhausted. Facility of transportation to market will be aided by railways, but these are slow and costly to construct, and it will not pay to carry wheat by rail beyond a certain distance. These considerations show that the price of wheat tends to increase. On the other hand, the artificial impediments of taxation and customs duties tend to diminish as demand increases and prices rise.

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[1] Appendix M.

I have said that starvation may be averted through the laboratory. Before we are in the grip of actual dearth the Chemist will step in and postpone the day of famine to so distant a period that we, and our sons and grandsons, may legitimately live without undue solicitude for the future.

It is now recognised that all crops require what is called a 'dominant' manure. Some need nitrogen, some potash, others phosphates. Wheat pre-eminently demands nitrogen, fixed in the form of ammonia or nitric acid. All other necessary constituents exist in the soil; but nitrogen is mainly of atmospheric origin, and is rendered 'fixed' by a slow and precarious process which requires a combination of rare meteorological and geographical conditions to enable it to advance at a sufficiently rapid rate to become of commercial importance.

There are several sources of available nitrogen. The distillation of coal in the process of gas-making yields a certain amount of its nitrogen in the form of ammonia; and this product, as sulphate of ammonia, is a substance of considerable commercial value to gas companies. But the quantity produced is comparatively small; all Europe does not yield more than 400,000 annual tons, and, in view of the unlimited nitrogen required to substantially increase the world's wheat crop, this slight amount of coal ammonia is not of much significance. For a long time guano has been one of the most important sources of nitrogenous manures, but guano deposits are so near exhaustion that they may be dismissed from consideration.

Much has been said of late years, and many hopes raised by the discovery of Hellriegel and Wilfarth, that leguminous plants bear on their roots nodosities abounding in bacteria endowed with the property of fixing atmospheric nitrogen; and it is proposed that the necessary amount of nitrogen demanded by grain crops should be supplied to the soil by cropping it with clover and ploughing in the plant when its nitrogen assimilisation is complete. But it is questionable whether such a mode of procedure will lead to the lucrative stimulation of crops. It must be admitted that practice has long been ahead of science, and for ages farmers have valued and cultivated leguminous crops. The four-course rotation is turnips, barley, clover, wheat—a sequence popular more than two thousand years ago. On the Continent, in certain localities, there has been some extension of microbe cultivation; at home we have not reached even the experimental stage. Our present knowledge leads to the conclusion that the much more frequent growth of clover on the same land, even with successful microbe-seeding and proper mineral supplies, would be attended with uncertainty and difficulties. The land soon becomes what is called 'clover sick' and turns barren.

There is still another and invaluable source of fixed nitrogen. I mean the treasure locked up in the sewage and drainage of our towns. Individually the amount so lost is trifling, but multiply the loss by the number of inhabitants, and we have the startling fact that, in the United Kingdom, we are content to hurry down our drains and water courses, into the sea, fixed nitrogen to the value of no less than 16,000,000*l.* per annum. This unspeakable waste continues, and no effective and universal method is yet contrived of converting sewage into corn. Of this barbaric waste of manurial constituents Liebig, nearly half a century ago, wrote in these prophetic words : 'Nothing will more certainly consummate the ruin of England than a scarcity of fertilisers—it means a scarcity of food. It is impossible that such a sinful violation of the divine laws of Nature should for ever remain unpunished; and the time will probably come for England sooner than for any other country, when, with all her wealth in gold, iron, and coal, she will be unable to buy one-thousandth part of the food which she has, during hundreds of years, thrown recklessly away.'

The more widely this wasteful system is extended, recklessly returning to the sea what we have taken from the land, the more surely and quickly will the finite stocks of nitrogen locked up in the soils of the world become exhausted. Let us remember that the plant creates nothing; there is nothing in bread which is not absorbed from the soil, and unless the abstracted nitrogen is returned to the soil, its fertility must ultimately be exhausted. When we apply to the land nitrate of soda, sulphate of ammonia, or guano, we are drawing on the earth's capital, and our drafts will not perpetually be honoured. Already we see that a virgin soil cropped for several years loses its productive powers, and without artificial aid becomes infertile. Thus the strain to meet demands is increasingly great. Witness the yield of forty bushels of wheat per acre under favourable conditions, dwindling through exhaustion of soil to less than seven bushels of poor grain, and the urgency of husbanding the limited store of fixed nitrogen becomes apparent. The store of nitrogen in the atmosphere is practically unlimited, but it is fixed and rendered assimilable by plants only by cosmic processes of extreme slowness. The nitrogen which with a light heart we liberate in a battleship broadside, has taken millions of minute organisms patiently working for centuries to win from the atmosphere.[1]

The only available compound containing sufficient fixed nitrogen to be used on a world-wide scale as a nitrogenous manure is nitrate of soda, or Chili saltpetre. This substance occurs native over a narrow band of the plain of Tamarugal, in the northern provinces of Chili between the Andes and the coast hills. In this rainless district for countless ages the continuous fixation of atmospheric nitrogen by the soil, its conversion into nitrate by the slow transformation of billions of nitrifying organisms, its combination with soda, and the crystallisation of the nitrate have been steadily proceeding, until the nitrate fields of Chili have become of vast commercial importance, and promise to be of inestimably greater value in

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[1] Appendix N.

the future. The growing exports of nitrate from Chili at present amount to about 1,200,000 tons.

The present acreage devoted to the world's growth of wheat is about 163,000,000 acres. At the average of 12·7 bushels per acre this gives 2,070,000,000 bushels. But thirty years hence the demand will be 3,260,000,000 bushels, and there will be difficulty in finding the necessary acreage on which to grow the additional amount required. By increasing the present yield per acre from 12·7 to 20 bushels we should with our present acreage secure a crop of the requisite amount. Now from 12·7 to 20 bushels per acre is a moderate increase of productiveness, and there is no doubt that a dressing with nitrate of soda will give this increase and more.

The action of nitrate of soda in improving the yield of wheat has been studied practically by Sir John Lawes and Sir Henry Gilbert on their experimental field at Rothamstead. This field was sown with wheat for thirteen consecutive years without manure, and yielded an average of 11·9 bushels to the acre. For the next thirteen years it was sown with wheat, and dressed with 5 cwt. of nitrate of soda per acre, other mineral constituents also being present. The average yield for these years was 36·4 bushels per acre—an increase of 24·5 bushels. In other words, 22·86 lbs. of nitrate of soda produce an increase of one bushel of wheat.

At this rate, to increase the world's crop of wheat by 7·3 bushels, about 1½ cwt. of nitrate of soda must annually be applied to each acre. The amount required to raise the world's crop on 163,000,000 acres from the present supply of 2,070,000,000 bushels to the required 3,260,000,000 bushels will be 12 million tons distributed in varying amounts over the wheat-growing countries of the world. The countries which produce more than the average of 12·7 bushels will require less, and those below the average will require more; but, broadly speaking, about 12,000,000 tons annually of nitrate of soda will be required, in addition to the 1¼ million tons already absorbed by the world.

It is difficult to get trustworthy estimates of the amount of nitrate surviving in the nitre beds. Common rumour declares the supply to be inexhaustible, but cautious local authorities state that at the present rate of export, of over one million tons per annum, the raw material 'caliche,' containing from 25 to 50 per cent. nitrate, will be exhausted in from twenty to thirty years.

Dr. Newton, who has spent years on the nitrate fields, tells me there is a lower class material, containing a small proportion of nitrate, which cannot at present be used, but which may ultimately be manufactured at a profit. Apart from a few of the more scientific manufacturers, no one is sanguine enough to think this debatable material will ever be worth working. If we assume a liberal estimate for nitrate obtained from the lower grade deposit, and say that it will equal in quantity that from the richer quality, the supply may last, possibly, fifty years, at the rate of a million tons a year; but at the rate required to augment the world's supply of wheat to the point demanded thirty years hence it will not last more than four years.

I have passed in review all the wheat-growing countries of the world, with the exception of those whose united supplies are so small as to make little appreciable difference to the argument. The situation may be summed up briefly thus :—The world's demand for wheat—the leading bread-stuff—increases in a crescendo ratio year by year. Gradually all the wheat-bearing land on the globe is appropriated to wheat-growing, until we are within measurable distance of using the last available acre. We must then rely on nitrogenous manures to increase the fertility of the land under wheat, so as to raise the yield from the world's low average—12·7 bushels per acre—to a higher average. To do this efficiently and feed the bread-eaters for a few years will exhaust all the available store of nitrate of soda. For years past we have been spending fixed nitrogen at a culpably extravagant rate, heedless of the fact that it is fixed with extreme slowness and difficulty, while its liberation in the free state takes place always with rapidity and sometimes with explosive violence.

Some years ago Mr. Stanley Jevons uttered a note of warning as to the near exhaustion of our British coalfields. But the exhaustion of the world's stock of fixed nitrogen is a matter of far greater importance. It means not only a catastrophe little short of starvation for the wheat-eaters, but indirectly, scarcity for those who exist on inferior grains, together with a lower standard of living for meat-eaters, scarcity of mutton and beef, and even the extinction of gunpowder!

There is a gleam of light amid this darkness of despondency. In its free state nitrogen is one of the most abundant and pervading bodies on the face of the earth. Every square yard of the earth's surface has nitrogen gas pressing down on it to the extent of about seven tons—but this is in the *free* state, and wheat demands it *fixed*. To convey this idea in an object-lesson, I may tell you that, previous to its destruction by fire, Colston Hall, measuring 146 feet by 80 feet by 70 feet, contained 27 tons weight of nitrogen in its atmosphere ; it also contained one-third of a ton of argon. In the free gaseous state this nitrogen is worthless ; combined in the form of nitrate of soda it would be worth about 2,000*l*.

For years past attempts have been made to effect the fixation of atmospheric nitrogen, and some of the processes have met with sufficient partial success to warrant experimentalists in pushing their trials still further ; but I think I am right in saying that no process has yet been brought to the notice of scientific or commercial men which can be considered successful either as regards cost or yield of product. It is possible, by several methods, to fix a certain amount of atmospheric nitrogen ; but to the best of my knowledge no process has hitherto converted more than a small amount, and this at a cost largely in excess of the present market value of fixed nitrogen.

The fixation of atmospheric nitrogen therefore is one of the great discoveries awaiting the ingenuity of chemists. It is certainly deeply important in its practical bearings on the future welfare and happiness of the civilised races of mankind. This unfulfilled problem, which so far has eluded the strenuous attempts of those who have tried to wrest the secret from nature, differs materially from other chemical discoveries which are in the air, so to speak, but are not yet matured. The fixation of nitrogen is vital to the progress of civilised humanity. Other discoveries minister to our increased intellectual comfort, luxury, or convenience; they serve to make life easier, to hasten the acquisition of wealth, or to save time, health, or worry. The fixation of nitrogen is a question of the not far distant future. Unless we can class it among certainties to come the great Caucasian race will cease to be foremost in the world, and will be squeezed out of existence by races to whom wheaten bread is not the staff of life.

Let me see if it is not possible even now to solve the momentous problem. As far back as 1892 I exhibited, at one of the Soirées of the Royal Society, an experiment on 'The Flame of Burning Nitrogen.' I showed that nitrogen is a combustible gas, and the reason why when once ignited the flame does not spread through the atmosphere and deluge the world in a sea of nitric acid is that its igniting point is higher than the temperature of its flame—not, therefore, hot enough to set fire to the adjacent mixture. But by passing a strong induction current between terminals the air takes fire and continues to burn with a powerful flame, producing nitrous and nitric acids. This inconsiderable experiment may not unlikely lead to the development of a mighty industry destined to solve the great food problem. With the object of burning out nitrogen from air so as to leave argon behind, Lord Rayleigh fitted up apparatus for performing the operation on a larger scale, and succeeded in effecting the union of 29·4 grammes of mixed nitrogen and oxygen at an expenditure of one horse-power. Following these figures it would require one Board of Trade unit to form 74 grammes of nitrate of soda, and therefore 14,000 units to form one ton. To generate electricity in the ordinary way with steam engines and dynamos, it is now possible with a steady load night and day, and engines working at maximum efficiency, to produce current at a cost of one-third of a penny per Board of Trade unit. At this rate one ton of nitrate of soda would cost 26*l.* But electricity from coal and steam engines is too costly for large industrial purposes; at Niagara, where water power is used, electricity can be sold at a profit for one-seventeenth of a penny per Board of Trade unit. At this rate nitrate of soda would cost not more than 5*l.* per ton. But the limit of cost is not yet reached, and it must be remembered that the initial data are derived from small scale experiments, in which the object was not economy, but rather to demonstrate the practicability of the combustion method, and to utilise it for isolating argon. Even now electric nitrate at 5*l.* a ton compares favourably with Chili nitrate at 7*l.* 10*s.* a ton; and all experience shows that when the road has been pointed out by a small laboratory experiment, the industrial operations that may follow are always conducted at a cost considerably lower than could be anticipated from the laboratory figures.

Before we decide that electric nitrate is a commercial possibility, a final question must be mooted. We are dealing with wholesale figures and must take care that we are not simply shifting difficulties a little further back without really diminishing them. We start with a shortage of wheat, and the natural remedy is to put more land under cultivation. As the land cannot be stretched, and there is so much of it and no more, the object is to render the available area more productive by a dressing with nitrate of soda. But nitrate of soda is limited in quantity, and will soon be exhausted. Human ingenuity can contend even with these apparently hopeless difficulties. Nitrate can be produced artificially by the combustion of the atmosphere. Here we come to finality in one direction; our stores are inexhaustible. But how about electricity? Can we generate enough energy to produce 12,000,000 tons of nitrate of soda annually? A preliminary calculation shows that there need be no fear on that score; Niagara alone is capable of supplying the required electric energy without much lessening its mighty flow.

The future can take care of itself. The artificial production of nitrate is clearly within view, and by its aid the land devoted to wheat can be brought up to the 30 bushels per acre standard. In days to come, when the demand may again overtake supply, we may safely leave our successors to grapple with the stupendous food problem.

And, in the next generation, instead of trusting mainly to food-stuffs which flourish in temperate climates, we probably shall trust more and more to the exuberant food-stuffs of the tropics, where, instead of one yearly sober harvest, jeopardised by any shrinkage of the scanty days of summer weather, or of the few steady inches of rainfall, Nature annually supplies heat and water enough to ripen two or three successive crops of food-stuffs in extraordinary abundance. To mention one plant alone, Humboldt—from what precise statistics I know not—computed that, acre for acre, the food-productiveness of the banana is 133 times that of wheat—the unripe banana, before its starch is converted into sugar, is said to make excellent bread.

Considerations like these must in the end determine the range and avenues of commerce, perhaps the fate of continents. We must develop and guide Nature's latent energies, we must utilise her inmost workshops, we must call into commercial existence Central Africa and Brazil to redress the balance of Odessa and Chicago.

Having kept you for the last half-hour rigorously chained to earth, disclosing dreary possibilities, it will be a relief to soar to the heights of pure science and to discuss a point or two touching its latest achievements and aspirations. The low temperature researches which bring such renown to Professor Dewar and to his laboratory in the Royal Institution have been crowned during the present year by the conquest of one of Nature's most defiant strongholds. On the 10th of last May Professor Dewar wrote to me these simple but victorious words: 'This evening I have succeeded in liquefying both hydrogen and helium. The second stage of low temperature work has begun.' Static hydrogen boils at a temperature of 238° C. at ordinary pressure, and at 250° C. in a vacuum, thus enabling us to get within 23° C. of absolute zero. The density of liquid hydrogen is only one-fourteenth that of water, yet in spite of such a low density it collects well, drops easily, and has a well-defined meniscus. With proper isolation it will be as easy to manipulate liquid hydrogen as liquid air.

The investigation of the properties of bodies brought near the absolute zero of temperature is certain to give results of extraordinary importance. Already platinum resistance thermometers are becoming useless, as the temperature of boiling hydrogen is but a few degrees from the point where the resistance of platinum would be practically nothing, or the conductivity infinite.

Several years ago I pondered on the constitution of matter in what I ventured to call the fourth state. I endeavoured to probe the tormenting mystery of the atom. What *is* the atom? Is a single atom in space solid, liquid, or gaseous. Each of these states involves ideas which can only pertain to vast collections of atoms. Whether, like Newton, we try to visualise an atom as a hard, spherical body, or, with Boscovitch and Faraday, to regard it as a centre of force, or accept the vortex atom theory of Lord Kelvin, an isolated atom is an unknown entity difficult to conceive. The properties of matter—solid, liquid, gaseous—are due to molecules in a state of motion. Therefore, matter as we know it involves essentially a mode of motion; and the atom itself—intangible, invisible, and inconceivable—is its material basis, and may, indeed, be styled the only true *matter*. The space involved in the motions of atoms has no more pretension to be called matter than the sphere of influence of a body of riflemen—the sphere filled with flying leaden missiles—has to be called lead. Since what we call matter essentially involves a mode of motion, and since at the temperature of absolute zero all atomic motions would stop, it follows that matter as we know it would at that paralysing temperature probably entirely change its properties. Although a discussion of the ultimate absolute properties of matter is purely speculative, it can hardly be barren, considering that in our laboratories we are now within moderate distance of the absolute zero of temperature.

I have dwelt on the value and importance of nitrogen, but I must not omit to bring to your notice those little known and curiously related elements which during the past twelve months have been discovered and partly described by Professor Ramsay and Dr. Travers. For many years my own work has been among what I may call the waste heaps of the mineral elements. Professor Ramsay is dealing with vagrant atoms of an astral nature. During the course of the present year he has announced the existence of no fewer than three new gases—krypton, neon, and metargon. Whether these gases, chiefly known by their spectra, are true unalterable elements, or whether they are compounded of other known or unknown bodies, has yet to be proved. Fellow workers freely pay tribute to the painstaking zeal with which Professor Ramsay has conducted a difficult research, and to the philosophic subtlety brought to bear on his investigations. But, like most discoverers, he has not escaped the flail of severe criticism.

There is still another claimant for celestial honours. Professor Nasini tells us he has discovered, in some volcanic gases at Pozzuoli, that hypothetical element Coronium, supposed to cause the bright line 5316·9 in the spectrum of the sun's corona. Analogy points to its being lighter and more diffusible than hydrogen, and a study of its properties cannot fail to yield striking results. Still awaiting discovery by the fortunate spectroscopist are the unknown celestial elements Aurorium, with a characteristic line at 5570·7—and Nebulum, having two bright lines at 5007·05 and 4959·02.

The fundamental discovery by Hertz, of the electro-magnetic waves predicted more than thirty years ago by Clerk Maxwell, seems likely to develop in the direction of a practical application which excites keen interest—I mean the application to electric signalling across moderate distances without connecting wires. The feasibility of this method of signalling has been demonstrated by several experimenters at more than one meeting of the British Association, though most elaborately and with many optical refinements by Oliver Lodge at the Oxford meeting in 1894. But not until Signor Marconi induced the British Post-Office and Foreign Governments to try large scale experiments did wireless signalling become generally and popularly known or practically developed as a special kind of telegraphy. Its feasibility depends on the discovery of a singularly sensitive detector for Hertz waves—a detector whose sensitiveness in some cases seems almost to compare with that of the eye itself. The fact noticed by Oliver Lodge in 1889, that an infinitesimal metallic gap subjected to an electric jerk became conducting, so as to complete an electric circuit, was rediscovered soon afterwards in a more tangible and definite form and applied to the detection of Hertz waves by M. E. Branly. Oliver Lodge then continued the work, and produced the *vacuum filing-tube* coherers with automatic tapper-back, which are of acknowledged practical service. It is this varying continuity of contact under the influence of extremely feeble electric stimulus alternating with mechanical tremor, which, in combination with the mode of producing the waves revealed by Hertz, constitutes the essential and fundamental feature of 'wireless telegraphy.' There is a curious and widely spread misapprehension about coherers, to the effect that to make a coherer work the wave must fall upon it. Oliver Lodge has disproved this fallacy. Let the wave fall on a suitable receiver, such as a metallic wire or, better still, on an arrangement of metal wings resembling a Hertz sender, and the waves set up oscillating currents which may be led by wires (enclosed in metal pipes) to the coherer. The coherer acts apparently by a species of end-impact of the oscillatory current, and does not need to be attacked in the flank by the waves themselves. This interesting method of signalling—already developing in Marconi's hands into a successful practical system which inevitably will be largely used in lighthouse and marine work—presents more analogy to optical signals by flash-light than to what is usually understood as electric telegraphy; notwithstanding the fact that an ordinary Morse instrument at one end responds to the movements of a key at the other, or, as arranged by Alexander Muirhead, a siphon recorder responds to an automatic transmitter at about the rate of slow cable telegraphy. But although no apparent optical apparatus is employed, it remains true that the impulse travels from sender to receiver by essentially the same process as that which enables a flash of magnesium powder to excite a distant eye.

The phenomenon discovered by Zeeman, that a source of radiation is affected by a strong magnetic field in such a way that light of one refrangibility becomes divided usually into three components, two of which are displaced by diffraction analysis on either side of the mean position and are oppositely polarised to the third or residual constituent, has been examined by many observers in all countries. The phenomenon has been subjected to photography with conspicuously successful results by Professor T. Preston in Dublin and by Professor Michelson and Dr. Ames and others in America.

It appears that the different lines in the spectrum are differently affected, some of them being tripled with different grades of relative intensity, some doubled, some quadrupled, some sextupled, and some left unchanged. Even the two components of the D lines are not similarly influenced. Moreover, whereas the polarisation is usually such as to indicate that motions of a negative ion or electron constitute the source of light, a few lines are stated by the observers at Baltimore, who used what they call the 'small' grating of 5 inches width ruled with 65,000 lines, to be polarised in the reverse way.

Further prosecution of these researches must lead to deeper insight into molecular processes and the mode in which they affect the ether; indeed already valuable theoretic views have been promulgated by H. A. Lorenz, J. Larmor, and G. F. Fitzgerald, on the lines of the radiation theory of Dr. Johnstone Stoney; and the connection of the new phenomena with the old magnetic rotation of Faraday is under discussion. It is interesting to note that Faraday and a number of more recent experimenters were led by theoretical considerations to look for some such effect; and though the inadequate means at their disposal did not lead to success, nevertheless a first dim glimpse of the phenomenon was obtained by M. Fievez, of the Royal Observatory at Brussels, in 1885.

It would be improper to pass without at least brief mention the remarkable series of theoretic papers by Dr. J. Larmor, published by the Royal Society, on the relationship between ether and matter. By the time these researches become generally intelligible they may be found to constitute a considerable step towards the further mathematical analysis and interpretation of the physical universe on the lines initiated by Newton.

In the mechanical construction of Röntgen ray tubes I can record a few advances: the most successful being the adoption of Professor Silvanus P. Thompson's suggestion of using for the anti-cathode a metal of high atomic weight. Osmium and iridium have been used with advantage, and osmium anti-cathode tubes are now a regular article of manufacture. As long ago as June 1896, X-ray tubes with metallic uranium anti-cathodes were made in my own laboratory, and were found to work better than those with platinum. The difficulty of procuring metallic uranium prevented these experiments from being continued. Thorium anti-cathodes have also been tried.

Röntgen has drawn fresh attention to a fact very early observed by English experimenters—that of the non-homogeneity of the rays and the dependence of their penetrating power on the degree of vacuum; rays generated in high vacua have more penetrative power than when the vacuum is less high. These facts are familiar to all who have exhausted focus tubes on their own pumps. Röntgen suggests a convenient phraseology; he calls a low vacuum tube, which does not emit the highly penetrating rays, a 'soft' tube, and a tube in which the exhaustion has been pushed to an extreme degree, in which highly penetrating rays predominate, a 'hard' tube. Using a 'hard' tube he took a photograph of a double-barrelled rifle, and showed not only the leaden bullets within the steel barrels but even the wads and the charges.

Benoit has re-examined the alleged relation between density and opacity to the rays, and finds certain discrepancies. Thus, the opacity of equal thicknesses of palladium and platinum are nearly equal whilst their densities and atomic weights are very different, those of palladium being about half those of platinum.

At the last meeting of the British Association visitors saw—at the McGill University—Professors Cox and Callendar's apparatus for measuring the velocity of Röntgen rays. They found it to be certainly greater than 200 kilometres per second. Majorana has made an independent determination, and finds the velocity to be 600 kilometres per second with an inferior limit certainly of not less than 150 kilometres per second. It may be remembered that J. J. Thomson has found for cathode rays a velocity of more than 10,000 kilometres per second, and it is extremely unlikely that the velocity of Röntgen rays will prove to be less.

Trowbridge has verified the fact, previously announced by Professor S. P. Thompson, that fluor-spar, which by prolonged heating has lost its power of luminescing when re-heated, regains the power of thermo-luminescence when exposed to Röntgen rays. He finds that this restoration is also effected by exposure to the electric glow discharge, but not by exposure to ultra-violet light. The difference is suggestive.

As for the action of Röntgen rays on bacteria, often asserted and often denied, the latest statement by Dr. H. Rieder, of Munich, is to the effect that bacteria are killed by the discharge from 'hard' tubes. Whether the observation will lead to results of pathologic importance remains to be seen. The circumstance that the normal retina of the eye is slightly sensitive to the rays is confirmed by Dorn and by Röntgen himself.

The essential wave-nature of the Röntgen rays appears to be confirmed by the fact ascertained by several of our great mathematical physicists, that light of excessively short wave-length would be but slightly absorbed by ordinary material media, and would not in the ordinary sense be refracted at all. In fact a theoretic basis for a comprehension of the Röntgen rays had been propounded before the rays were discovered. At the Liverpool meeting of the British Association, several speakers, headed by Sir George Stokes, expressed their conviction that the disturbed electric field caused by the sudden stoppage of the motion of an electrically charged atom yielded the true explanation of the phenomena extraneous to the Crookes high vacuum tubes—phenomena so excellently elaborated by Lenard and by Röntgen. More recently, Sir George Stokes has re-stated his 'pulse' theory, and fortified it with arguments which have an important bearing on the whole theory of the refraction of light. He still holds to their essentially transverse nature, in spite of the absence of polarisation, an absence once more confirmed by the careful experiments of Dr. L. Graetz. The details of this theory are in process of elaboration by Professor J. J. Thomson.

Meantime, while the general opinion of physicists seems to be settling towards a wave or ether theory for the Röntgen rays, an opposite drift is apparent with respect to the physical nature of the cathode rays; it becomes more and more clear that cathode rays consist of electrified atoms or ions in rapid progressive motion. My idea of a fourth state of matter, propounded in 1881,[1] and at first opposed at home and abroad, is now becoming accepted. It is supported by Professor J. J. Thomson:[2] Dr. Larmor's theory[3] likewise involves the idea of an ionic substratum of matter; the view is also confirmed by Zeeman's phenomenon. In Germany—where the term cathode ray was invented almost as a protest against the theory of molecular streams propounded by me at the Sheffield meeting of the British Association in 1879—additional proofs have been

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[1] *Phil. Trans.*, Part 2, 1881, pp. 433–4.

[2] *Phil. Mag.*, October 1897, p. 312.

[3] *Ibid.*, December 1897, p. 506.

produced in favour of the doctrine that the essential fact in the phenomenon is electrified Radiant Matter.

The speed of these molecular streams has been approximately measured, chiefly by aid of my own discovery nearly twenty years ago, that their path is curved in a magnetic field, and that they produce phosphorescence where they impinge on an obstacle. The two unknown quantities, the charge and the speed of each atom, are measurable from the amount of curvature and by means of one other independent experiment.

It cannot be said that a complete and conclusive theory of these rays has yet been formulated. It is generally accepted that collisions among particles, especially the violent collisions due to their impact on a massive target placed in their path, give rise to the interesting kind of extremely high frequency radiation discovered by Röntgen. It has, indeed, for some time been known that whereas a charged body in motion constitutes an electric current, the sudden stoppage, or any violent acceleration of such a body, must cause an alternating electric disturbance, which, though so rapidly decaying in intensity as to be practically 'dead beat,' yet must give rise to an ethereal wave or pulse travelling with the speed of light, but of a length comparable to the size of the body whose sudden change of motion caused the disturbance. The emission of a high-pitched musical sound from the jolting of a dustman's cart (with a spring bell hung on it) has been suggested as an illustration of the way in which the molecules of any solid not at absolute zero may possibly emit such rays.

If the target on to which the electrically-charged atoms impinge is so constituted that some of its minute parts can thereby be set into rhythmical vibration, the energy thus absorbed reappears in the form of light, and the body is said to phosphoresce. The efficient action of the phosphorescent target appears to depend as much on its physical and molecular as on its chemical constitution. The best known phosphori belong to certain well-defined classes, such as the sulphides of the alkaline-earthy metals, and some of the so-called rare earths; but the phosphorescent properties of each of these groups are profoundly modified by an admixture of foreign bodies—witness the effect on the lines in the phosphorescent spectrum of yttrium and samarium produced by traces of calcium or lead. The persistence of the samarium spectrum in presence of overwhelming quantities of other metals, is almost unexampled in spectroscopy: thus one part of samaria can easily be seen when mixed with three million parts of lime.

Without stating it as a general rule, it seems as if with a non-phosphorescing target the energy of molecular impact reappears as pulses so abrupt and irregular that, when resolved, they furnish a copious supply of waves of excessively short wave-length, in fact, the now well-known Röntgen rays. The phosphorescence so excited may last only a small fraction of a second, as with the constituents of yttria, where the duration of the different lines varies between the 0·003 and the 0·0009 second;

or it may linger for hours, as in the case of some of the yttria earths, and especially with the earthy sulphides, where the glow lasts bright enough to be commercially useful. Excessively phosphorescent bodies can be excited by light waves, but most of them require the stimulus of electrical excitement.

It now appears that some bodies, even without special stimulation, are capable of giving out rays closely allied, if not in some cases identical, with those of Professor Röntgen. Uranium and thorium compounds are of this character, and it would almost seem from the important researches of Dr. Russell, that this ray-emitting power may be a general property of matter, for he has shown that nearly every substance is capable of affecting the photographic plate if exposed in darkness for sufficient time.

No other source for Röntgen rays but the Crookes tube has yet been discovered, but rays of kindred sorts are recognised. The Becquerel rays, emitted by uranium and its compounds, have now found their companions in rays—discovered almost simultaneously by Curie and Schmidt—emitted by thorium and its compounds. The thorium rays affect photographic plates through screens of paper or aluminium, and are absorbed by metals and other dense bodies. They ionise the air, making it an electrical conductor; and they can be refracted and probably reflected, at least diffusively. Unlike uranium rays, they are not polarised by transmission through tourmaline, therefore resembling in this respect the Röntgen rays.

Quite recently M. and Mme. Curie have announced a discovery which, if confirmed, cannot fail to assist the investigation of this obscure branch of physics. They have brought to notice a new constituent of the uranium mineral pitchblende, which in a 400-fold degree possesses uranium's mysterious power of emitting a form of energy capable of impressing a photographic plate and of discharging electricity by rendering air a conductor. It also appears that the radiant activity of the new body, to which the discoverers have given the name of Polonium, needs neither the excitation of light nor the stimulus of electricity; like uranium, it draws its energy from some constantly regenerating and hitherto unsuspected store, exhaustless in amount.

It has long been to me a haunting problem how to reconcile this apparently boundless outpour of energy with accepted canons. But as Dr. Johnstone Stoney reminds me, the resources of molecular movements are far from exhausted. There are many stores of energy in nature that may be drawn on by properly constituted bodies without very obvious cause. Some time since I drew attention to the enormous amount of locked up energy in the ether; nearer our experimental grasp are the motions of the atoms and molecules, and it is not difficult mentally so to modify Maxwell's demons as to reduce them to the level of an inflexible law and thus bring them within the ken of a philosopher in search of a new tool. It is possible to conceive a target capable of mechanically sifting from the molecules of the surrounding air the quick from the slow movers. This sifting of the swift moving molecules is effected in liquids whenever they evaporate, and in the case of the constituents of the atmosphere, wherever it contains constituents light enough to drift away molecule by molecule. In my mind's eye I see such a target as a piece of metal cooler than the surrounding air acquiring the energy that gradually raises its temperature from the outstanding effect of all its encounters with the molecules of the air about it; I see another target of such a structure that it throws off the slow moving molecules with little exchange of energy, but is so influenced by the quick moving missiles that it appropriates to itself some of their energy. Let uranium or polonium, bodies of densest atoms, have a structure that enables them to throw off the slow moving molecules of the atmosphere, while the quick moving molecules, smashing on to the surface, have their energy reduced and that of the target correspondingly increased. The energy thus gained seems to be employed partly in dissociating some of the molecules of the gas (or in inducing some other condition which has the effect of rendering the neighbouring air in some degree a conductor of electricity) and partly in originating an undulation through the ether, which, as it takes its rise in phenomena so disconnected as the impacts of the molecules of the air, must furnish a large contingent of light waves of short wave-length. The shortness in the case of these Becquerel rays appears to approach without attaining the extreme shortness of ordinary Röntgen rays. The reduction of the speed of the quick moving molecules would cool the layer of air to which they belong; but this cooling would rapidly be compensated by radiation and conduction from the surrounding atmosphere; under ordinary circumstances the difference of temperature would scarcely be perceptible, and the uranium would thus appear to perpetually emit rays of energy with no apparent means of restoration.

The total energy of both the translational and internal motions of the molecules locked up in quiescent air at ordinary pressure and temperature is about 140,000 foot-pounds in each cubic yard of air. Accordingly the quiet air within a room 12 feet high, 18 feet wide, and 22 feet long contains energy enough to propel a one-horse engine for more than twelve hours. The store drawn upon naturally by uranium and other heavy atoms only awaits the touch of the magic wand of Science to enable the Twentieth Century to cast into the shade the marvels of the Nineteenth.

Whilst placing before you the labours and achievements of my comrades in Science I seize this chance of telling you of engrossing work of my own on the fractionation of yttria to which for the last eighteen years I have given ceaseless attention. In 1883, under the title of 'Radiant Matter Spectroscopy,' I described a new series of spectra produced by passing the phosphorescent glow of yttria, under molecular bombardment *in vacuo*, through a train of prisms. The visible spectra in time gave up their secrets, and were duly embalmed in the *Philosophical Transactions.* At the Birmingham meeting of the British Association in 1886 I brought the subject before the Chemical Section, of which I had the honour to be President. The results led to many speculations on the probable origin of all the elementary bodies—speculations that for the moment I must waive in favour of experimental facts.

There still remained for spectroscopic examination a long tempting stretch of unknown ultra-violet light, of which the exploration gave me no rest. But I will not now enter into details of the quest of unknown lines. Large quartz prisms, lenses, and condensers, specially sensitised photographic films capable of dealing with the necessary small amount of radiation given by feebly phosphorescing substances,[1] and above all tireless patience in collating and interpreting results, have all played their part. Although the research is incomplete I am able to announce that among the groups of rare earths giving phosphorescent spectra in the visible region there are others giving well defined groups of bands which can only be recorded photographically. I have detected and mapped no less than six such groups extending to λ 3060.

Without enlarging on difficulties, I will give a brief outline of the investigation. Starting with a large quantity of a group of the rare earths in a state of considerable purity, a particular method of fractionation is applied, splitting the earths into a series of fractions differing but slightly from each other. Each of these fractions, phosphorescing *in vacuo*, is arranged in the spectrograph, and a record of its spectrum photographed upon a specially prepared sensitive film.

In this way, with different groups of rare earths, the several invisible bands were recorded—some moderately strong, others exceedingly faint. Selecting a portion giving a definite set of bands, new methods of fractionation were applied, constantly photographing and measuring the spectrum of each fraction. Sometimes many weeks of hard experiment failed to produce any separation, and then a new method of splitting up was devised and applied. By unremitting work—the solvent of most difficulties—eventually it was possible to split up the series of bands into various groups. Then, taking a group which seemed to offer possibilities of reasonably quick result, one method after another of chemical attack was adopted, with the ultimate result of freeing the group from its accompanying fellows and increasing its intensity and detail.

As I have said, my researches are far from complete, but about one of the bodies I may speak definitely. High up in the ultra-violet, like a faint nebula in the distant heavens, a group of lines was detected, at first feeble and only remarkable on account of their isolation. On further purification these lines grew stronger. Their great refrangibility cut them off

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[1] In this direction I am glad to acknowledge my indebtedness to Dr. Schuman, of Leipzig, for valuable suggestions and detail of his own apparatus, by means of which he has produced some unique records of metallic and gaseous spectra of lines of short wave-length.

from other groups. Special processes were employed to isolate the earth, and using these lines as a test, and appealing at every step to the spectrograph, it was pleasant to see how each week the group stood out stronger and stronger, while the other lines of yttrium, samarium, ytterbium, &c., became fainter, and at last, practically vanishing, left the sought-for group strong and solitary. Finally, within the last few weeks, hopefulness has emerged into certainty, and I have absolute evidence that another member of the rare earth groups has been added to the list. Simultaneously with the chemical and spectrographic attack, atomic weight determinations were constantly performed.

As the group of lines which betrayed its existence stand alone, almost at the extreme end of the ultra-violet spectrum, I propose to name the newest of the elements Monium, from the Greek *μόνος*, alone. Although caught by the searching rays of the spectrum, Monium offers a direct contrast to the recently discovered gaseous elements, by having a strongly marked individuality; but although so young and wilful, it is willing to enter into any number of chemical alliances.

Until my material is in a greater state of purity I hesitate to commit myself to figures; but I may say that the wave-lengths of the principal lines are 3120 and 3117. Other fainter lines are at 3219, 3064, and 3060. The atomic weight of the element, based on the assumption of R_2O_3, is not far from 118—greater than that accepted for yttrium and less than that for lanthanum.

I ought almost to apologise for adding to the already too long list of elements of the rare earth class—the asteroids of the terrestrial family. But as the host of celestial asteroids, unimportant individually, become of high interest when once the idea is grasped that they may be incompletely coagulated remains of the original nebula, so do these elusive and insignificant rare elements rise to supreme importance when we regard them in the light of component parts of a dominant element, frozen in embryo, and arrested in the act of coalescing from the original protyle into one of the ordinary and law-abiding family for whom Newlands and Mendeleeff have prepared pigeon-holes. The new element has another claim to notice. Not only is it new in itself, but to discover it a new tool had to be forged for spectroscopic research.

Further details I will reserve for that tribunal before whom every aspirant for a place in the elemental hierarchy has to substantiate his claim.

These, then, are some of the subjects, weighty and far-reaching, on which my own attention has been chiefly concentrated. Upon one other interest I have not yet touched—to me the weightiest and the farthest reaching of all.

No incident in my scientific career is more widely known than the part I took many years ago in certain psychic researches. Thirty years have passed since I published an account of experiments tending to show that outside our scientific knowledge there exists a Force exercised by intelligence differing from the ordinary intelligence common to mortals. This fact in my life is of course well understood by those who honoured me with the invitation to become your President. Perhaps among my audience some may feel curious as to whether I shall speak out or be silent. I elect to speak, although briefly. To enter at length on a still debatable subject would be unduly to insist on a topic which—as Wallace, Lodge, and Barrett have already shown—though not unfitted for discussion at these meetings, does not yet enlist the interest of the majority of my scientific brethren. To ignore the subject would be an act of cowardice—an act of cowardice I feel no temptation to commit.

To stop short in any research that bids fair to widen the gates of knowledge, to recoil from fear of difficulty or adverse criticism, is to bring reproach on Science. There is nothing for the investigator to do but to go straight on, 'to explore up and down, inch by inch, with the taper his reason'; to follow the light wherever it may lead, even should it at times resemble a will-o'-the-wisp. I have nothing to retract. I adhere to my already published statements. Indeed, I might add much thereto. I regret only a certain crudity in those early expositions which, no doubt justly, militated against their acceptance by the scientific world. My own knowledge at that time scarcely extended beyond the fact that certain phenomena new to science had assuredly occurred, and were attested by my own sober senses, and better still, by automatic record. I was like some two-dimensional being who might stand at the singular point of a Riemann's surface, and thus find himself in infinitesimal and inexplicable contact with a plane of existence not his own.

I think I see a little farther now. I have glimpses of something like coherence among the strange elusive phenomena; of something like continuity between those unexplained forces and laws already known. This advance is largely due to the labours of another Association of which I have also this year the honour to be President—the Society for Psychical Research. And were I now introducing for the first time these inquiries to the world of science I should choose a starting-point different from that of old. It would be well to begin with *telepathy*; with the fundamental law, as I believe it to be, that thoughts and images may be transferred from one mind to another without the agency of the recognised organs of sense—that knowledge may enter the human mind without being communicated in any hitherto known or recognised ways.

Although the inquiry has elicited important facts with reference to the Mind, it has not yet reached the scientific stage of certainty which would entitle it to be usefully brought before one of our Sections. I will therefore confine myself to pointing out the direction in which scientific investigation can legitimately advance. If telepathy take place we have two physical facts—the physical change in the brain of A, the suggester, and the analogous physical change in the brain of B, the recipient of the suggestion. Between these two physical events there must exist a train of physical causes. Whenever the connecting sequence of intermediate causes begins to be revealed the inquiry will then come within the range of one of the Sections of the British Association. Such a sequence can only occur through an intervening medium. All the phenomena of the universe are presumably in some way continuous, and it is unscientific to call in the aid of mysterious agencies when with every fresh advance in knowledge it is shown that ether vibrations have powers and attributes abundantly equal to any demand—even to the transmission of thought. It is supposed by some physiologists that the essential cells of nerves do not actually touch, but are separated by a narrow gap which widens in sleep while it narrows almost to extinction during mental activity. This condition is so singularly like that of a Branly or Lodge coherer as to suggest a further analogy. The structure of brain and nerve being similar, it is conceivable there may be present masses of such nerve coherers in the brain whose special function it may be to receive impulses brought from without through the connecting sequence of ether waves of appropriate order of magnitude. Röntgen has familiarised us with an order of vibrations of extreme minuteness compared with the smallest waves with which we have hitherto been acquainted, and of dimensions comparable with the distances between the centres of the atoms of which the material universe is built up; and there is no reason to suppose that we have here reached the limit of frequency. It is known that the action of thought is accompanied by certain molecular movements in the brain, and here we have physical vibrations capable from their extreme minuteness of acting direct on individual molecules, while their rapidity approaches that of the internal and external movements of the atoms themselves.

Confirmation of telepathic phenomena is afforded by many converging experiments, and by many spontaneous occurrences only thus intelligible. The most varied proof, perhaps, is drawn from analysis of the sub-conscious workings of the mind, when these, whether by accident or design, are brought into conscious survey. Evidence of a region, below the threshold of consciousness, has been presented, since its first inception, in the *Proceedings of the Society for Psychical Research*; and its various aspects are being interpreted and welded into a comprehensive whole by the pertinacious genius of F. W. H. Myers. Concurrently, our knowledge of the facts in this obscure region has received valuable additions at the hands of labourers in other countries. To mention a few names out of many, the observations of Richet, Pierre Janet, and Binet (in France), of Breuer and Freud (in Austria), of William James (in America) have strikingly illustrated the extent to which patient experimentation can probe subliminal processes, and can thus learn the lessons of alternating personalities, and abnormal states. Whilst it is clear that our knowledge of subconscious mentation is still to be developed, we must beware of rashly assuming that all variations from the normal waking condition are necessarily morbid. The human race has reached no fixed or changeless ideal; in every direction there is evolution as well as disintegration. It would be hard to find instances of more rapid progress, moral and physical, than in certain important cases of cure by suggestion—again to cite a few names out of many—by Liébeault, Bernheim, the late Auguste Voisin, Bérillon (in France), Schrenck-Notzing (in Germany), Forel (in Switzerland), van Eeden (in Holland), Wetterstrand (in Sweden), Milne-Bramwell and Lloyd Tuckey (in England). This is not the place for details, but the *vis medicatrix* thus evoked, as it were, from the depths of the organism, is of good omen for the upward evolution of mankind.

A formidable range of phenomena must be scientifically sifted before we effectually grasp a faculty so strange, so bewildering, and for ages so inscrutable, as the direct action of mind on mind. This delicate task needs a rigorous employment of the method of exclusion—a constant setting aside of irrelevant phenomena that could be explained by known causes, including those far too familiar causes, conscious and unconscious fraud. The inquiry unites the difficulties inherent in all experimentation connected with *mind*, with tangled human temperaments and with observations dependent less on automatic record than on personal testimony. But difficulties are things to be overcome even in the elusory branch of research known as Experimental Psychology. It has been characteristic of the leaders among the group of inquirers constituting the Society for Psychical Research to combine critical and negative work with work leading to positive discovery. To the penetration and scrupulous fair-mindedness of Professor Henry Sidgwick and of the late Edmund Gurney is largely due the establishment of canons of evidence in psychical research, which strengthen while they narrow the path of subsequent explorers. To the detective genius of Dr. Richard Hodgson we owe a convincing demonstration of the narrow limits of human continuous observation.

It has been said that 'Nothing worth the proving can be proved, nor yet disproved.' True though this may have been in the past, it is true no longer. The science of our century has forged weapons of observation and analysis by which the veriest tyro may profit. Science has trained and fashioned the average mind into habits of exactitude and disciplined perception, and in so doing has fortified itself for tasks higher, wider, and incomparably more wonderful than even the wisest among our ancestors imagined. Like the souls in Plato's myth that follow the chariot of Zeus, it has ascended to a point of vision far above the earth. It is, henceforth, open to science to transcend all we now think we know of matter, and to gain new glimpses of a profounder scheme of Cosmic Law.

An eminent predecessor in this chair declared that 'by an intellectual necessity he crossed the boundary of experimental evidence, and discerned in that matter, which we in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the potency and promise of all terrestrial life.' I should prefer to reverse the apophthegm, and to say that in life I see the promise and potency of all forms of matter.

In old Egyptian days a well-known inscription was carved over the portal of the temple of Isis :—'I am whatever hath been, is, or ever will be ; and my veil no man hath yet lifted.' Not thus do modern seekers after truth confront Nature—the word that stands for the baffling mysteries of the universe. Steadily, unflinchingly, we strive to pierce the inmost heart of Nature, from what she is to re-construct what she has been, and to prophesy what she yet shall be. Veil after veil we have lifted, and her face grows more beautiful, august, and wonderful, with every barrier that is withdrawn.

APPENDIX.

In preparing the part of this Address dealing with the world's supply and demand for wheat, and the conclusions based thereon, I have been materially assisted by Mr. C. Wood Davis, of Kansas, U.S.A. Apart from information obtained from Mr. Davis's articles in 'The Forum,' the 'North-Western Miller,' the 'New York Sun,' and other papers, I am indebted to him for valuable manuscript information on matters of detail. Mr. Davis appears to be the only person dealing with this problem in a manner to determine such essential factors as average acre yields for long periods, unit requirements for each of the primary food staples of the temperate zones, and the ratios existing during different recent periods between the consuming element and acres employed in the production of each of such primary food staples. His scientific method enables him to ascertain the acreage requirements of the separate national populations, and of the 'bread-eating' world as a whole. Information has also been obtained from the 'Agricultural Returns of the United Kingdom,' the official 'Reports on Agricultural Depression,' and the Annual Reports of the United States Secretary of Agriculture ; likewise from papers and articles by Sir John Lawes, Sir H. Gilbert, Major Craigie, Mr. W. E. Bear, Mr. Warington, Professor E. M. Shelton, Mr. R. F. Crawford, Dr. Newton, and Mr. W. Walgrave Chapman. The 'Journal of the Royal Agricultural Society,' the 'Journal of the Royal Statistical Society,' the 'Journal of the Board of Agriculture,' and other periodicals have also been laid under contribution. I am also indebted to the various official publications of the Government of Canada, the Department of Agriculture, Queensland, and to friends all over the world.

A.

Last year there were under corn crops in the United Kingdom :—

Wheat . . .	3,025 sq. miles, producing 56,296,000 bushels.	
Barley . . .	3,447	,,
Oats . . .	6,580	,,
Total . .	13,052	,,

There is now about as much area under mixed cereals as would have to be devoted solely to wheat to make our country self-supporting.

B.—*The World's Wheat Crop of* 1897–98 *from Contributory Areas.*[1]

	Bushels
United States	510,000,000
France	240,000,000
Russia and Poland	230,000,000
Austria-Hungary	135,000,000
Germany	105,000,000
Spain	96,000,000
Italy	82,000,000
Trans-Caucasia and Siberia	64,000,000
Argentina	60,000,000
United Kingdom	56,000,000
Canada	55,000,000
Roumania	43,000,000
Caucasia (Northern)	40,000,000
Australasia	38,000,000
Bulgaria	30,000,000
Turkey in Europe	22,000,000
Belgium	16,000,000
Chili	15,000,000

	Bushels
Uruguay, Brazil, &c.	9,000,000
Portugal	7,000,000
Servia	6,000,000
Holland	5,000,000
Denmark	5,000,000
Sweden and Norway	5,000,000
Greece	4,000,000
Switzerland	4,000,000
Bosnia, Montenegro, Cyprus, &c.	4,000,000
South Africa	4,000,000
	1,890,000,000
Add imports from Asia and North Africa	31,000,000
Total available wheat supply	1,921,000,000

Table showing the Variations in the Bread-eating Populations and the Available Supply of Wheat in the Five Yearly Periods from 1878 *to* 1897, *in Millions of Bushels, and Annual Averages.*

Years	Bread-eating Populations	Wheat grown by 'Contributory areas'	Imports from Asia and North Africa	Remainders from former harvest	Total available supply	Required for seed and food	Supply in excess of year's needs
1877–81	407·0	1797·0	13·8	174·4	1985·2	1812·8	172·4
1882–86	432·8	1937·6	41·4	294·0	2273·0	1946·0	327·0
1887–91	460·8	2043·5	43·2	260·2	2346·9	2102·0	244·9
1892–96	490·9	2199·2	23·6	265·4	2488·2	2233·8	254·4
1897–98	510·0	1890·0	31·0	300·0	2221·0	2310·0	Deficit 89·0

C.

The 'world's demand' for wheat is as follows :—

	Bushels
United Kingdom, about	180,000,000
Belgium	24,000,000
Germany	35,000,000
Holland	13,000,000
Switzerland	13,500,000
France	40,000,000
Sweden	4,000,000

	Bushels
Spain	10,000,000
Portugal	4,000,000
Greece	4,500,000
Islands and tropical lands	28,000,000
Total	356,000,000

D.

Between 1882 and 1897 the wheat crops were so abundant that over 1,200 million bushels were added to our stores, beside large accumulations of rye. During this time of golden harvests, the exports from Russia increased,

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[1] Outside the better known areas of wheat supply a certain proportion of wheat comes from India, Persia, Syria, Anatolia and North Africa. But it is impossible to get accurate figures as to acreage and yield from these countries; as bread-eaters derive less than one per cent. of their supplies from these outlying sources, it is convenient to call the ordinary areas 'contributory areas,' and to deal with the external areas no further than to show the volume of imports yielded from year to year.

in consequence of the Russian decline in unit consumption of 13·5 per cent. These reserves have been gradually drawn upon, but enough still remained to obscure the fact that the 1895–6 harvest was 75,000,000 bushels, and the 1896–7 harvest was 138,000,000 bushels below current needs.

The following table[1] has been compiled from statistics carefully collected by Mr. Davis and other observers. The prophetic figures are on the assumption that population, unit consumption, and steady development will increase during the next forty-three years as they have increased since 1871 :—

Date	Bread-eaters	Food and Seed[2] required per unit. Bushels	Requiring bushels of wheat	With yields averaging 12·7 bushels acreage required
1871	371,000,000	4·15	1,540,000,000	121,000,000
1881	416,000,000	4·38	1,822,000,000	143,000,000
1891	472,600,000	4·50	2,127,000,000	167,000,000
1898	516,500,000	4·50	2,324,000,000	183,000,000
1901	536,100,000	4·50	2,412,000,000	190,000,000
1911	603,700,000	4·50	2,717,000,000	214,000,000
1921	674,000,000	4·50	3,033,000,000	239,000,000
1931	746,100,000	4·50	3,357,000,000	264,000,000
1941	819,200,000	4·50	3,686,000,000	290,000,000

To supply these bread-eaters, the world inhabited by bread-eating populations grew the following quantities of wheat in each of the designated five-year periods :—

Years	Bushels—Annual average	Acres—Annual average
1871–75	1,580,000,000, grown on	131,000,000
1876–80	1,746,000,000 ,,	143,000,000
1881–85	1,926,000,000 ,,	152,000,000
1886–90	1,987,000,000 ,,	154,000,000
1891–95	2,201,000,000 ,,	159,000,000

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[1] I have taken the unit consumption including seed at 4·5 bushels and the yield per acre at 12·7 bushels per annum, this being the average of the whole world. The exact yield varies with the country in which wheat is grown, as shown by the following table :—

Average Yield of Wheat per Acre in—

	Bushels		Bushels
Denmark	41·8	Poland	16·2
United Kingdom	29·1	Canada	15·5
New Zealand	25·5	Argentina	13·0
Norway	25·1	Italy	12·1
Germany	23·2	United States (mean)	12·0
Belgium	21·5	India	9·2
Holland	21·5	Russia in Europe	8·6
France	19·4	Algeria	7·5
Hungary	18·6	South Australia	7·0
Roumania	18·5	Australasia	6·8
Austria	16·3		

[2] The seed quota is kept constant at 0·6 bushel per unit per annum, but the unit food requirements are found to increase in each five-yearly period. There has been a steady increase of unit wheat requirements by reason of the decrease of unit consumption of rye, maslin, spelt, and buckwheat.

Within the same periods wheat was imported from Asia and North Africa by the 'bread-eating' countries as follows :—

Years	Bushels—Annual average	Acres—Annual average
1871–75	8,000,000, the net product of	750,000
1876–80	12,000,000 „ „	1,120,000
1881–85	36,000,000 „ „	3,360,000
1886–90	39,000,000 „ „	3,640,000
1891–95	34,000,000 „ „	3,200,000

Broadly speaking, 2,000 million bushels are now consumed in the countries where they are grown, either as food or for seed, while the balance is exported.

E.

At the present time the disproportion is even higher, owing to unit consumption gradually increasing from year to year, accompanied by slow shrinkage in the wheat area.

—	1871	1884	1897	Per cent. of Increase or Decrease in Twenty-six Years
Population . .	371,000,000	432,800,000	510,000,000	37·5 increase.
Wheat acres . .	125,800,000	154,300,000	158,000,000	25·6 increase.
Rye acres . .	111,000,000	110,300,000	106,500,000	4·1 decrease.

The area planted with the two great bread-making grains is actually less now than thirteen years ago, despite enormous additions to the population. The area under *all* the bread-making grains is absolutely 2·2 per cent. less than thirteen years ago, notwithstanding an increase of one-fifth in requirements for bread.

F.

Notwithstanding this expansion the supplies of wheat were hardly sufficient for the food demands of the world. As the area under wheat has increased that under rye has diminished, with the result that scarcely an acre has been added to the world's wheat and rye since 1890 ; and there was in 1897 a deficit in the two principal bread-making grains of more than 600,000,000 bushels.

G.

Stocks of wheat and flour in the United States were, relatively to population, probably never smaller, if so small as now. The following table (from *Bradstreet*) shows the visible supply of wheat in the States on June 1 since 1893 :—

	Bushels		Bushels
1893	93,700,000	1896	71,300,000
1894	80,500,000	1897	39,200,000
1895	72,800,000	1898	32,500,000

H.

In 1896 the area under wheat in the Governments of Russia and Poland was 36,000,000 acres. But the yearly consumption of wheat per head during the last ten years has declined 14 per cent., and the consumption of bread is quite 30 per cent. less than is required to keep the population in health. The grain reserved for seed has likewise decreased—the peasantry limiting their sowing with the rise of taxation. The reduction of 14 per cent. in the unit consumption of bread in Russia has added, during the last eighteen years, 1,360,000,000 bushels to the general wheat supply. This factitious excess temporarily staved off scarcity in Europe.

I.

In the year 1897 there were 2,371,441 acres under cultivation in Manitoba, out of a total of 13,051,375 acres. The total area includes water courses, lakes, forests, towns, and farms, land unsuitable for wheat-growing, and land required for other crops.

J.

The most trustworthy estimates give Canada a wheat area of not more than six millions of acres in the next twelve years, increasing to a maximum of twelve millions of acres in twenty-five years. The development of this promising area necessarily must be slow, since prairie land cannot be laid under wheat in advance of a population sufficient to supply the needful labour at seed time and harvest. As population increases so do home demands for wheat.

Acreage, Crop, and Exports of Wheat from Canada from 1891 *to* 1896.

Year	Population	Acres	Total bushels	Bushels exported
1891 .	4,833,000	2,690,000	62,600,000	3,000,000
1892 .	4,885,000	2,910,000	49,700,000	10,200,000
1893 .	4,936,000	2,800,000	42,700,000	11,000,000
1894 .	4,986,000	2,550,000	44,600,000	11,000,000
1895 .	5,040,000	2,560,000	57,500,000	9,200,000
1896 .	5,090,000	2,700,000	40,800,000	10,400,000
1897 .	5,140,000	2,900,000	56,600,000	8,000,000

The net exports average 8,970,000 bushels yearly, being 24·3 per cent. of the net product.

K.

The land under wheat in Austro-Hungary, according to the latest official figures, is eleven million acres. The 1897–8 crop, including that of Croatia-Slavonia, is fifty-five million bushels below that of 1896–7, and as exports during the last five years have averaged less than 4,000,000 bushels per annum, the imports of wheat are expected to be large.

L.

So long ago as April 16, 1891, the following statement by a leading Indian economist appeared in the 'Daily Englishman' of Calcutta:— 'People do not realise the fact that all the wheat India produces is required for home consumption, and that this fact is not likely to be realised until a serious disaster occurs, and that even now less than 9 per cent is exported. It is a self-evident fact that a slight expansion of consumption, or a partial failure of crops of other food grains, will be sufficient to absorb the small proportion now exported. Besides, we have a steady increase of consumption, in consequence of the natural growth of the population, as well as in the gradual improvement of the condition of a considerable part of the people in the cities. I believe that, comparatively speaking, India will in a few years cease to export wheat, and soon thereafter become an importing country.'

M.

An average wheat crop on the 1897–8 acreage would be 2,070,000,000 bushels. Adding to this 1,270,000,000 bushels, makes a grand total of 3,340,000,000 bushels. But the estimate in Appendix D shows that in the year 1931 the bread-eaters will require 3,357,000,000 bushels. Thus there will be in 1931 a deficiency of 17,000,000 bushels, unless the average yield per acre be increased.

N.

Sir Andrew Noble informs me that a first-class battleship would carry about sixty-three tons of cordite, and we may suppose that in a general action forty tons of this would be expended. Now at Trafalgar, Nelson had twenty-seven line-of-battle ships, and the allied forces thirty-three. If we suppose a similar number of modern battleships and first-class cruisers to be engaged, and each to expend forty tons of cordite, the total volume of nitrogen set free would be 302,400 cubic metres, or about 380 tons, equivalent to 2,300 tons of nitrate of soda.

REPORTS

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STATE OF SCIENCE.

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Corresponding Societies Committee.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Sir DOUGLAS GALTON, Dr. J. G. GARSON, Sir J. EVANS, Mr. J. HOPKINSON, Mr. W. WHITAKER, Mr. G. J. SYMONS, Professor T. G. BONNEY, Mr. CUTHBERT PEEK, Mr. HORACE T. BROWN, Rev. J. O. BEVAN, *and* Professor W. W. WATTS.

The Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following Report of the proceedings of the Conference held at Bristol.

The Council nominated Mr. W. Whitaker, F.R.S., Chairman, and Mr. T. V. Holmes, Secretary to the Bristol Conference. These nominations were confirmed by the General Committee at a meeting held at Bristol on Wednesday, September 7. The meetings of the Conference were held at University College on Thursday, September 8, and Tuesday, September 13, at 3 P.M. The following Corresponding Societies nominated as delegates to represent them at the Bristol meeting:—

Andersonian Naturalists' Society . .	Professor M. Laurie, D.Sc.
Belfast Naturalists' Field Club. . .	William Gray, M.R.I.A,
Belfast Natural History and Philosophical Society	Alexander Tate, M.Inst.C.E.
Berwickshire Naturalists' Club . . .	G. P. Hughes, J.P.
Birmingham Natural History and Philosophical Society.	Alfred Browett.
Bristol Naturalists' Society	F. W. Stoddart.
Buchan Field Club	John Gray, B.Sc.
Burton-on-Trent Natural History and Archæological Society.	Philip B. Mason, F.L.S.
Caradoc and Severn Valley Field Club .	Professor W. W. Watts, F.G.S.
Cardiff Naturalists' Society	J. T. Thompson, M.B.
Chesterfield and Midland Counties Institution of Engineers	M. H. Mills, M.Inst.C.E.

Croydon Microscopical and Natural History Club.	W. F. Stanley, F.G.S.
Dorset Natural History and Antiquarian Field Club.	Dr. H. Colley March.
East Kent Natural History Society	Mrs. Edith Abbott.
Essex Field Club	T. V. Holmes, F.G.S.
Federated Institution of Mining Engineers	M. H. Mills, M.Inst.C.E.
Glasgow Geological Society	J. B. Murdoch.
Glasgow Natural History Society	G. F. Scott-Elliott, M.A.
Hampshire Field Club	T. W. Shore, F.G.S.
Hertfordshire Natural History Society	J. Hopkinson, F.L.S.
Holmesdale Natural History Club	Miss Ethel Sargant.
Ireland, Statistical and Social Inquiry Society of	Professor Bastable, M.A.
Isle of Man Natural History and Antiquarian Society	P. M. C. Kermode.
Leeds Naturalists' Club	Harold Wager, F.L.S.
Liverpool Engineering Society	Professor H. S. Hele-Shaw, M.Inst.C.E.
Liverpool Geographical Society	Professor Gonner, M.A.
Liverpool Geological Society	Professor Herdman, F.R.S.
Malton Field Naturalists' and Scientific Society.	M. B. Slater, F.L.S.
Manchester Geographical Society	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society	Mark Stirrup, F.G.S.
Manchester Microscopical Society	F. W. Hembry.
Norfolk and Norwich Naturalists' Society	Clement Reid, F.G.S.
North Staffordshire Naturalists' Field Club	Dr. Wheelton Hind, F.G.S.
North of England Institute of Mining Engineers	T. Forster Brown, M.Inst. C.E.
Northamptonshire Natural History Society	Beeby Thomson, F.G.S.
Perthshire Society of Natural Science	Dr. H. R. Mill, F.R.S.E.
Rochdale Literary and Scientific Society	J. R. Ashworth, B.Sc.
Scotland, Mining Institute of	James Barrowman.
Somersetshire Archæological and Natural History Society.	Lieut.-Col. J. R. Bramble, F.S.A.
South Eastern Union of Scientific Societies	Dr. G. Abbott.
Toronto Astronomical and Physical Society	W. F. Denning, F.R A.S.
Tyneside Geographical Society	G. E. Smithson.
Warwickshire Naturalists' and Archæologists' Field Club.	William Andrews, F.G.S.
Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A.
Yorkshire Geological and Polytechnic Society.	William Cash, F.G.S.
Yorkshire Naturalists' Union	Harold Wager, F.L.S.

First Conference, Bristol, September 8, 1898.

The Corresponding Societies Committee were represented by Mr. W. Whitaker (Chairman of the Conference), Dr. Garson, Mr. Hopkinson, Professor Meldola, Mr. G. J. Symons, and Mr. T. V. Holmes (Secretary).

The following Report, a copy of which was in the hands of every delegate present, was taken as read :—

The Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following report.

The Committee observe with satisfaction that the corresponding societies steadily increase in number, and that the total number of the members composing them also increases. For example, in the British Association Report of the Bath Meeting in 1888 there is a list of 55 corresponding societies, having a total of 18,950 members. The Toronto Report of last year shows 69 corresponding societies, having a total of 22,395 members. On the other hand, the average number of members in each society appears to have slightly decreased, having been between 344 and 345 in 1888, and between 324 and 325 in 1897. But this is accounted for by the collapse of the two federations—the Midland Union and the Cumberland and Westmoreland Association—and the withdrawal of the Royal Scottish Geographical Society between the two periods. For in 1888 these three associations numbered among them 4,006 members, as many as would be found in eleven or twelve average societies.

The Committee are also pleased to know that as the great majority of the societies, the main purpose of whose existence is local scientific investigation, are now on the list of corresponding societies, the index of their more important papers approximates to completeness more and more each year as a record of local work. But they nevertheless regret the absence from their index of papers read before certain societies of more or less importance which from various causes are not on their list. Primarily by the term 'local' the British Association implies that a society so classed has its headquarters out of London. But it can hardly be expected that societies which have long flourished in cities such as Edinburgh and Dublin will feel that they are 'local,' as they might be justified in doing if their headquarters were at Aberdeen or Belfast, Leeds or Birmingham, or as if they recognised some county as their sphere of action. Then, many societies have been formed for the study and advancement of some science or group of sciences in various parts of the country, with little reference to local phenomena, which societies appeal to their members rather as being conveniently near than in any other way.

But though societies such as have just been alluded to may be little more 'local' in feeling and in the nature of their work than London societies it must sometimes happen that papers devoted to local scientific investigations are published by them. The Committee therefore regret the absence from their list of papers of local interest which have been published by such societies as the following :—

The Royal Irish Academy, Royal Dublin Society, Institution of Civil Engineers of Ireland, Royal Society of Edinburgh, Botanical Society of Edinburgh, Royal Physical Society of Edinburgh, Liverpool Biological Society, Liverpool Naturalists' Field Club, Manchester Literary and Philosophical Society.

Fortunately, in most cases, information as to the titles and authors of papers read before local societies which are not corresponding societies of the Association may be obtained from the 'Official Year-book of the Scientific and Learned Societies of Great Britain and Ireland,' C. Griffin & Co., London. The 'Year-book' appears every spring, and contains lists of papers read in the previous year. It will be found that the 'Year-book' and the British Association 'Index' combined leave little to be desired by the inquirer after papers on any locality in the British Isles.

The following Societies have been added to the list of the Corresponding Societies :—

The Astronomical and Physical Society of Toronto.
The Hull Geological Society.
The South-Eastern Union of Naturalists' Societies.

The Chairman, Mr. Whitaker, then opened the proceedings. He said that it had become usual to bring some special subject for discussion before the first meeting of the Conference. On that occasion he wished to draw their attention to that of Coast Erosion. All persons were interested in the scenery of our shores, whether living in counties bordering the sea or wholly inland. Moreover, some counties having a coast line had few or no local scientific societies, and might need help from others farther from the sea. It was now possible to obtain maps on the scale of six inches to the mile for all localities, and on these measurements could be made from the edge of the cliffs, at any given time, to the nearest roads, footpaths, hedges, cottages or other objects, and the amount of land lost since the map was made could be accurately ascertained. Of course, all such measurements should be dated. Very good work had been done in the past with old one-inch maps, but many precautions were necessary in using them which were needless with six-inch maps. In illustration of the loss which has been sustained in certain places, he might mention Sheppey. The Geologists' Association had made three excursions there. On their first visit the church and churchyard of Warden were untouched. Some years later the churchyard was found to have been partly destroyed, and coffins were seen sticking out from the edge of the cliff. This year neither church nor churchyard could be seen. There was another form of encroachment by the sea which had been well displayed during a recent visit of the Geologists' Association to Aldeburgh in Suffolk. There they found many cottages, sheds, and gardens more or less injured, or even destroyed by the heaping up of masses of shingle in or against them, the result of a storm in November 1897, which had caused much damage over many miles of our coast. Much injury to land adjoining the sea was often done by blown sand, which here and there had been driven to considerable heights, and covered areas of some breadth, as he had recently seen on the northern coast of Cornwall. The help of the photographer was extremely valuable in giving an unassailable record of a past state of things; the damage done by natural forces being often greatly obscured in a comparatively short period of time. The photo-theodolite might often be found useful in this matter. Turning to the economical aspect of the question, Mr. Whitaker remarked that there were two things especially worthy of attention, (1) the removal of shingle from the shore, (2) the quarrying of stone on the faces of sea cliffs. There were certainly some places at which the removal of shingle from the shore should never be allowed ; nowhere should it be permitted without some thought as to the probable result. And the quarrying of stone on the face of a sea cliff often had a powerful influence in aiding the erosive agencies of Nature. Archæologists would be interested in noting spots where old British camps had been partly destroyed by the sea ; examples of which he (Mr. Whitaker) had noticed on the Chalk of Dorset, and on the much harder rocks which form the cliffs of northern Cornwall. Observations of this kind were not only calculated to make us realise the differences between the outlines of the coast now and in prehistoric times, but they also led us to try and imagine the probable changes of the future. His remarks were intended simply to start a discussion on a subject in which he had always taken great interest.

Mr. T. V. Holmes said that, as secretary of the Corresponding Societies Committee, he had been requested to write to three gentlemen, known as having taken much interest in Coast Erosion, to ask them if they would be good enough to take part in this discussion. One of these gentlemen, Captain McDakin, regretted his inability to attend, the other two, Mr. W. H. Wheeler and Mr. A. T. Walmisley, were, he believed, present. The Chairman had also asked Prof. Armstrong, Mr. Cornish, and Mr. Spiller to attend.

Mr. W. H. Wheeler had a paper to read on this subject on Monday, which embodied the results of his observations on Coast Erosion. In his opinion the movement of shingle along the shore was due to the action of the tides and not of the winds.

Professor H. E. Armstrong recommended the taking of photographs by means of the photo-theodolite instead of in the ordinary way.

Mr. Gray said, that the Belfast Naturalists' Field Club had already noted a great many points with regard to Coast Erosion in their district, and were going to issue a special report on the subject next year.

Mr. A. T. Walmisley had always advocated the protection of the foreshore by means of groynes. Sea-walls were very useful in the protection of cliffs when placed not close to, but a short distance in front of, the cliff to be protected. Waves then might rush up the face of the wall without touching the cliff.

Mr. Vaughan Cornish had come to the conclusion that the protection of one part of the shore was a bad thing for the rest of the district. Considering how restricted was the area with which lords of manors, corporations, and local authorities of all kinds concerned themselves, he thought that no local work of shore protection should be begun till it had been sanctioned by a Government Board. In any study of the results of Coast Erosion, the Coastguard would be able to render most valuable assistance. They were always tramping along the shore, they were to a considerable extent trained observers, and they might be simultaneously at work all round the British Isles, if the consent of the Admiralty could be obtained to their co-operation in the study of Coast Erosion.

Mr. G. J. Symons mentioned, in illustration of the danger of allowing people to do as they pleased on the shore, that his grandfather at the beginning of this century was building martello towers on the southern shores of England. One day he observed some men in a boat off Bognor taking stones to the mainland, and with them building a house. His grandfather warned them that the sea would reclaim the stones some day. And recently he had learned that the people there had been put to much trouble in endeavouring to restrain the inroads of the sea.

Mr. Clement Reid referred to the waste of land along the west coast; and said that it was most necessary in that district to have the new ordnance survey maps.

Mr. J. Spiller gave details as to the encroachments of the sea at Southwold in Suffolk. Quite recently masses of shingle had been thrown on the land so as to cover a whole pasture field. Nothing had hitherto been done to check these inroads beyond the provision of groynes. Many old landmarks had disappeared, and the gun-battery was a thing of the past. He thought Government intervention desirable, and that it would be a good thing to obtain the co-operation of the Coastguard in noting the changes on our shores.

Mr. Tate said that the amount of Coast Erosion differed very much in different districts. In some quarters there seemed to be a feeling in favour of restrictions on the protective measures allowable in any given case. It would, however, be difficult to obtain Government regulation unless it should appear that there was a manifest public need for it.

Mr. Wheeler thought that the retention of a considerable mass of shingle in front of a place would furnish a better protection than a sea wall. He greatly approved of an attempt to obtain the services of the Coastguard in making a survey of the coast, as at present he had found it very difficult to get trustworthy evidence, the most opposite stories being told in almost every case. People did not know because they did not really observe, while the occupation of a Coastguardsman necessarily made him observant. He did not approve, however, of general Government regulations.

Mr. Scott-Elliot thought that it would be a very good thing to obtain the co-operation of the Coastguard.

Professor Meldola remarked that the general opinion certainly appeared to be in favour of an attempt to obtain the approval of the Admiralty for their wish to secure the co-operation of the Coastguard, and the Conference would be acting within its powers in sending up a recommendation on the subject. He would therefore move :—

'That the Council of the British Association be requested to bring under the notice of the Admiralty, the importance of securing systematic observations upon the erosion of the sea coasts of the United Kingdom, and that the co-operation of the Coastguard might be profitably secured for this purpose.'

Mr. Wheeler asked whether the matter should not be referred to the Coast Erosion Committee of the British Association.

The Chairman reminded the last speaker that the labours of that Committee were ended. He thought that the Coastguard were perfectly capable of doing the work proposed, and that they would be pleased to do it.

Discussion then ensued on various points of detail, among others on the question where specimens of shingle collected at certain spots in order to note its movements along our shores should be stored. In this Messrs. Wheeler, Shore, Symons, and Gray took part.

Professor Meldola remarked that the resolution did not commit either the Admiralty or themselves to any particular line. Should the Admiralty ask how it was suggested that the Coastguard should make observations, then it might be for that Conference to draw up rules for their adoption.

Mr. Gray seconded the resolution, and after some remarks from Mr. Sowerbutts, Professor Meldola, the Chairman, and Mr. Hopkinson, it was put to the meeting and carried.

Professor Meldola then announced that he had just received the following letter from Professor Watts :—

Corndon, Worcester Road, Sutton, Surrey: September 7, 1898.

DEAR SIR,—It might be as well to report to the Conference of Delegates that the B. A. Geological Photographs Committee has formed a collection of duplicate photographs and slides, which can be sent during the winter to any local scientific society desiring to make use of them.

It consists of about 250 prints in two albums, and about 100 lantern slides.

Faithfully yours,
W. W. WATTS.

Dr. Abbott wished to know if there would be any opportunity of discussing the subject of the Federation of Local Societies at that meeting of the British Association. The Chairman thought that it might be brought forward at the next meeting of the Conference.

Second Meeting of the Conference, September 13.

The Corresponding Societies Committee were represented by Professor Meldola, Mr. Whitaker, Dr. Garson, Rev. J. O. Bevan, Mr. Hopkinson, Mr. G. J. Symons, and Mr. T. V. Holmes (Secretary).

The Chairman (Mr. Whitaker) announced that action had been taken with regard to the Resolution on Coast Erosion passed at their last meeting. It had been submitted to the Committees of the Geological and of the Geographical Sections, both of which unanimously supported the recommendations contained in it.

Dr. Garson then took the chair, Mr. Whitaker being obliged to leave.

Uniformity of Size of Pages of Scientific Societies' Publications.

Professor S. P. Thompson said that he had been asked to bring before the Conference a matter on which a Committee of the British Association had already made one Report, and still continued to exist, with the intention of making another. This question was the importance of adopting one or two uniform standard sizes for the pages of scientific publications. All who were engaged in any kind of scientific investigation were greatly indebted to the reprinted papers on the subjects in which they were interested which were sent to them by their fellow workers. And all recognised the great advantage given by uniformity in the size of their pages, which permitted them to be bound together and permanently preserved. The great desirability of promoting uniformity in size of page had caused Section A some four years ago to promote the formation of a Committee whose object was to prescribe the adoption of certain standard octavo and quarto sizes. The Report of this Committee would be found in the Ipswich Report of the British Association, pp. 77–79 (1895).

The standard octavo size recommended was: Paper *demy*, the pages measuring 14 cm. × 22 cm., or, when uncut, $5\frac{5}{8}$ in. × $8\frac{3}{4}$ in. The width, measured from the stitching to the outer edge of the printed matter, to be 12 cm., or $4\frac{5}{8}$ in., and the height of the printed portion, including the running headline, to be 18 cm., or 7 in.

The standard quarto size: Paper *demy*, the pages measuring, when uncut, 22 cm. × 28·5 cm., or 8¾ in. wide × 11¼ in. high. Letter-press not to exceed the measurements of 7½ in. by 9 in.

It was also desirable that each article should begin a page, and that, if possible, it should begin on a right-hand page. It is then practicable to bind that article with others without binding up with it the last page of another. Many other details dealing with what is desirable in scientific publications may be found, with illustrations, in the Report of the Committee in the Ipswich volume. A method of splitting printed pages, useful in separating successive articles in a journal, for collections of pamphlets, was incidentally described.[1]

The Chairman (Dr. Garson) remarked that they were greatly indebted to Professor Thompson, who had raised a question of much practical importance.

Professor Meldola thought that they were much indebted to Professor Thompson for bringing this matter forward. To endeavour to promote the uniformity of size which had just been advocated was one of the original functions of these Conferences, and he hoped that the suggestions of Professor Thompson might bear fruit. It was the duty of the Corresponding Societies Committee to collect the publications of the Corresponding Societies at Burlington House, but, on gazing at the shelves on which they lay, a great want of uniformity in size became manifest. Some societies also did themselves injustice as regards paper and printing.

Mr. Tate was glad that the matter had been brought forward, on account of the great advantage arising from being able to bind together papers and pamphlets issued by various societies. He would bring the subject before the Society he represented.

Mr. Clement Reid suggested that the original paging should be preserved in reprints.

The Rev. J. O. Bevan hoped that when the matter was brought before the Corresponding Societies by the delegates the general interest in uniformity might be dwelt upon, as many societies might otherwise feel indifferent towards it.

Mr. Gray said that as most papers on local subjects were reprinted, these suggestions would probably determine the form of the reprints.

Mr. Abbott thought that it would be well if the secretaries of societies issuing publications irregular in size and form had their attention drawn to the subject.

Mr. Hopkinson was acquainted with the publications of most of the local societies, and thought that the number which were irregular in size and form was very small indeed. The chief offenders were societies which, from want of sufficient funds, published reprints from local newspapers. He thought each paper should begin at the top of a

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[1] At the request of the Chairman of the Committee, the following note is added on the method of splitting a page of printed matter described verbally to the Committee:—Gum to each face of the page that is to be split a rather larger leaf of paper of a thin tough quality—resembling bank-note paper. The projecting edges should not be gummed. Let them become quite dry. Procure two small wooden rollers, about 7 inches (or more) long and ¾ inch (or less) in diameter. Then put the edges of the prepared page between the rollers, and, grasping them in the hands, so roll the respective edges of the two leaves around the rollers as to peel them or tear them away from one another. The use of the rollers is to prevent the page from tearing irregularly. Finally, soak off the two leaves in water. Not every kind of printed paper can be split without tearing.—S. P. T.

page; but the suggestion that each paper should begin on the right-hand page could not always be adopted on account of the loss of space which would sometimes occur thereby where there were many short papers. The present discussion would probably be of more service in guiding new societies than in causing alterations in the publications of old ones, which would spoil the uniformity of a set of volumes.

The Chairman, Dr. Garson, thought that they should give their best thanks to Professor Thompson for bringing this matter before them. The time also was opportune, as we were nearly at the close of the nineteenth century, and the beginning of another century would be an excellent period for the commencement of a new series in cases where it was desirable in the interests of uniformity. The suggestion that reprints might be of one uniform size, even if the original publication were not so, was one of great importance. It might be worth while to take up the question of publications next year as a special subject, and it would be a good thing if the delegates would consider the matter during the winter and consult their societies upon it, so as to be able to discuss it with authority upon another occasion.

The Rev. J. O. Bevan suggested that they might ask the Corresponding Societies to come to some conclusion upon this question, and forward it to the secretary of the Committee.

Professor Meldola said that they would be quite prepared next year to name those societies which were offenders with respect to uniformity. Mr. Hopkinson had pointed out that they were few in number.

Mrs. Abbott suggested that it would be a good thing to offer information on the subject to as many societies as possible.

Lieut.-Col. Bramble asked what was to be done in the case of societies which had no delegates present.

The Chairman replied that the report of the Conference was sent to every society on their list. And any information applied for by other societies would be given.

SECTION A.

Mr. G. J. Symons, representing Section A, said that there was only one matter to which he wished to draw attention. Professor Milne, as most of them knew, was making some highly important observations on earthquake tremors. But he was then working in a house in the Isle of Wight, which was in so bad a sanitary state that many fears were entertained with regard to his health. It had been suggested that there were houses in Richmond Park well suited to be the scene of Professor Milne's labours, and that it might be well to approach the Government to see whether one of them could be obtained for him. If not, perhaps some rich man, on being made acquainted with the case, might lend a house for a few years. Nothing sumptuous was asked for, only quarters which were water-tight and healthy.

SECTION C.

Mr. Beeby Thompson said that a fine specimen of a Dinosaur had recently been discovered near Northampton. It would, however, be a very expensive task to uncover it carefully, and it was necessary that the work should be proceeded with without delay. He wished therefore either to obtain a grant from the British Association, or to induce any rich people who might hear of the case and be interested therein, to assist in providing the necessary funds.

The Chairman (Dr. Garson) thought that an effort should be made to bring the matter before the scientific societies of Northampton.

Mr. Gray stated that the Society he represented was second to none in its efforts to collect geological photographs. He thought much more might be done by other societies in that work.

SECTION H.

The Chairman wished to draw the attention of the Conference to the Ethnographical Survey, an investigation in which few local societies were co-operating. Full directions for guidance in the various departments of the work might be obtained from the papers issued by the Ethnographical Survey Committee. The amateur photographer would find a wide field of action in noting physical characteristics. The important point was to get a common standard of size, a very convenient one being one-seventh of the natural size. Another department was that of the ancient monuments and general archæology of a district. Then came the collection of its folklore, and the noting of local names and dialects.

Mr. Gray said that the Society he represented had much sympathy with the objects of the Ethnographical Survey Committee, especially as regards the cataloguing of antiquities. He had a list of all the Holy Wells of Antrim and Down, together with photographs of them. He much wished to obtain the co-operation of the Royal Society of Antiquaries of Ireland in order that a complete survey of Irish antiquities might be made.

The Chairman remarked that full instructions on all matters connected with the Ethnographical Survey could be obtained on application to the Secretary of the Committee, and it was resolved that the Secretary should be asked to write to the Royal Society of Antiquaries of Ireland pointing out the plans and objects of the Ethnographical Survey.

Mr. Browett said that he was much impressed by the importance and interest of the Survey, and would have much pleasure in mentioning it to the Council of his Society on his return. He thought, however, that it was desirable that one general plan should be sent to all the Corresponding Societies that the work might be done everywhere on the same lines.

Mr. Hartland, the Secretary of the Ethnographical Survey Committee, said that it would greatly help his Committee if each of the Corresponding Societies could see its way to take up one or more branches of this inquiry. He had explained at previous Conferences that it was by no means necessary that all branches should be taken up everywhere. The Committee would be thankful for local help in any department of their work. He would be happy to send to the Corresponding Societies all the information they might require as to the nature of the work and the way in which the Committee wished it to be carried on.

The Chairman hoped that the delegates would give some account to their respective Societies of the discussions which had taken place. The proceedings then terminated.

The Corresponding Societies of the British Association for 1898–99.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. A. D. Brownlie and C. Cunningham	181	None	2s. 6d.	Annals, occasionally
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	258	None	1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1862	Belfast Nat. F. C.	Museum, College Square. James St. J. Phillips	450	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Dr. J. Hardy, Oldcambus, Cockburnspath, N.B., and Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10s. 6d.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers, Congreve Street, Birmingham. W. P. Marshall and W. Boulton	254	None	1l. 1s.	Journal, bi-monthly; Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	E. A. Pankhurst, 3 Clifton Road, Brighton, and T. C. Clark	178	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	Theodore Fisher, M.D., 25 Pembroke Road, Clifton, Bristol	136	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	170	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	B. L. Oswell, 71 Spring Terrace Road, Burton-on-Trent	200	None	5s.	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury.	185	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	453	None	10s. 6d.	Transactions, annually.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln, and W. F. J. Shepheard	700	None	5s.	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	353	1l. 1s. None	Members 31s. 6d.; Associates and Students 20s.	Transactions of Federated Institution of Mining Engineers, about every month.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	180	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	John B. Cornish, Penzance	98	None	1l. 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. R. F. Grundy	230	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	350	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	Prof. T. Johnson, Science and Art Museum, Dublin	200	5s.	5s.	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. J. Maxwell Ross, Avenel, Dumfries	190	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc.	18 Watling Street, Canterbury. Stephen Horsley	58	None	10s.	'South-Eastern Naturalist,' annually.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, Tylehurst, Kirkcaldy, N.B.	10 Societies, 900 Membs.	None	Assessment of 4d. per member	Proceedings, occasionally.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	H. M. Cadell, B.Sc., 5 St. Andrew Square Edinburgh	253	10s. 6d.	12s. 6d.	Transactions, annually.

CORRESPONDING SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Essex Field Club, 1858	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	350	None	15*s.*	'Essex Naturalist,' quarterly, and 'Special Memoirs,' occasionally.
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, about every month.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Mearns, Glasgow	250	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	S. M. Wellwood, 207 Bath Street, Glasgow	332 Memb. 30 Assoc.	7*s.* 6*d.* None	Members 7*s.* 6*d.* Associates 5*s.*	Transactions and Proceedings, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	A. Freeland Fergus, M.D., 207 Bath Street, Glasgow	650	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C.	Literary and Philosophical Society's Rooms. C. E. Fox	110	None	2*s.* 6*d.*	'Halifax Naturalist,' every two months.
Hampshire Field Club, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	John Hopkinson, F.L.S., The Grange, St. Albans	220	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	83	10*s.*	10*s.*	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	Royal Institution. John W. Stather	65	None	5*s.*	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	175	None	5*s.* and 2*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, W. Lawson, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Dr. D. Forsyth, 2 Lifton Place, Leeds	100	None	5*s.*, 2*s.* 6*d.*, and 1*s.*	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds; E. B. Smith, St. Chad's Villa, Headingley, Leeds	170	None	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. J. M. Gimson	320 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liverpool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	383	None	Resident 1*l.* 1*s.* Non-Res. and Students 10*s.* 6*d.*	Transactions, annually.
Liverpool Geographical Society, 1892	Liverpool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Chapel Street, Liverpool	750	None	1*l.* 1*s.*	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liverpool Geol. Soc.	Royal Institution. H. C. Beasley	55	None	21*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	L'pool Lit. Phil. Soc.	Royal Institution. J. Maxwell McMaster	211	None	1*l.* 1*s.*; Ladies 10*s.* 6*d.*	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Museum, Yorkersgate, Malton, Yorkshire. F. Young	100	None	5*s.* and 2*s.* 6*d.*	Report, annually.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	143	2*s.* 6*d.*	Gentlemen 7*s.* 6*d.* Ladies and Non-Residents 5*s.*	Yn Lioar Manninagh, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	800	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly; 'Geography,' monthly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	5 John Dalton Street, Manchester. W. Saint and G. H. Winstanley	265	None	1*l.*	Transactions, eight or nine parts per annum.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, Manchester	213	– 5*s.* –	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. F. E.	203	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.

tory Society, 1864						
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Mining Offices, Barnsley	254	None	1*l.* 10*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich	256	None	5*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,200	None	21*s.* and 42*s.*	Transactions of Federated Institution of Mining Engineers, about every month.
North Staffordshire Field Club	N. Staff. F. C.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	400	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	150	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Henry Wilkins, 352 Alfreton Road, Nottingham	171	2*s.* 6*d.*	5*s.*	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	322 and 22 Associates	5*s.*	7*s.* 6*d.*	Report, annually; Meteorological Observations, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	Museum, Public Buildings, Penzance. Dr. H. Montgomerie	80	None	10*s.* 6*d.*	Report, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	312 Members and 40 Assoc. Members	2*s.* 6*d.* None	5*s.* 6*d.* 3*s.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105 Freehold Street, Rochdale	238	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	130	None	5*s.*	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of	Mining Inst. Scot.	James Barrowman, Staneacre, Hamilton, N.B.	466	None	42*s.* and 25*s.*	Transactions of the Mining Institute of Scotland, six times each year
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	600	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	L. Péringuey, South African Museum, Cape Town	123	None	2*l.* and 1*l.*	Transactions, annually.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union	George Abbott, M.R.C.S., 33 Upper Grosvenor Road, Tunbridge Wells	31 Societies	None	5*s.*	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M. Inst. C.E., 3 Newhall Street, Birmingham	167	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Federated Institution of Mining Engineers, about every month.
Toronto, Astronomical and Physical Society of	Toronto Astr. Phys. Soc.	Technical School Buildings. G. E. Lumsden	133	—	—	Transactions, annually.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,300	None	10*s.* and 5*s.*	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1858	Warw. N. A. F. C.	Museum, Warwick. T. W. Whitley, 20 Camberwell Terrace, Leamington	84	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	219	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	163	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., 259 Hyde Park Road, Leeds	431 and 2,383 Associates.	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	410	None	2*l.*	Report, annually.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by named Societies during the year ending June 1, 1898.

⁂ This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Correspondence sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

ALSTON, GARWOOD. Comparison of Evaporation Results in New South Wales and South Africa. 'Trans. S. African Phil. Soc.' IX. 8–19, 1897.

ANDSON, Rev. WM. The Meteorology of Dumfries for 1896. 'Trans. Dum. Gal. N. H. A. Soc.' No. 13, 33–38, 1898.

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HERBERT, J. H. The Solar Eclipse of August 9, 1896. 'Report Nott. Nat. Soc. 1896–7,' 13–35, 1897.

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Meteorological Observatory, Montreal.—Report of the Committee for the Establishment of a Meteorological Observatory on the Top of Mount Royal, Montreal, consisting of Professor H. L. CALLENDAR (*Chairman*), Professor C. H. MCLEOD (*Secretary*), Professor F. ADAMS, *and* Mr. R. F. STUPART.

The Committee desire this year to present an *interim* report, and to ask for reappointment, with a further grant of 50*l*. The object of the establishment of the observatory on the top of the mountain was to obtain simultaneous records of temperature, humidity, &c., for comparison with those taken at the College Observatory at the foot. The distance between the two stations is rather more than a mile, and the difference of altitude nearly 600 feet. A line consisting of four insulated copper wires was erected to connect the two observatories. As a preliminary experiment, an electrical thermometer was set up on the wooden tower on the summit of the mountain, and connected through the line to a recording instrument in the College Observatory. No difficulty was encountered in obtaining continuous records of the temperature on the summit in this manner. It is hoped that interesting results may be obtained by comparing continuous records of temperature at stations differing so considerably in altitude within a short distance of each other. The work has not yet progressed for a sufficient length of time to enable the Committee to report any general results, but the success of the method has been established, and it is intended, if possible, to further extend the method to the recording continuously at a distance of wind velocity and direction, barometric pressure, and humidity. The intensity of sunshine has been recorded for some months at the observatory by means of similar instruments, and it is hoped to demonstrate the possibility of obtaining complete and accurate records of *all* necessary meteorological data from a distant observatory in a more or less inaccessible situation (such as that on the summit of Ben Nevis), without the necessity of employing a special observer to make daily visits to the station.

Comparing and Reducing Magnetic Observations.—Report of the Committee, consisting of Professor W. G. ADAMS (*Chairman*), Dr. C. CHREE (*Secretary*), Lord KELVIN, Professor G. H. DARWIN, Professor G. CHRYSTAL, Professor A. SCHUSTER, Captain E. W. CREAK, the Astronomer Royal, Mr. WILLIAM ELLIS, and Professor A. W. RÜCKER.

THE Committee report that they have received the following two communications bearing on the comparison and reduction of magnetic observations :—

I. *Magnetic Results at Greenwich and Kew, discussed and compared,* 1889 to 1896. *By* WILLIAM ELLIS, *F.R.S.*

It is known that, in tabulating the photographic records of magnetic declination and horizontal and vertical forces at the Royal Observatory, Greenwich, it has been the custom to include all days, except those of occasional extreme disturbance, so that many days of considerable disturbance become included. It is also known that the diurnal inequality so calculated differs from that obtained by the use of methods such as those of Sabine and Wild. Theoretically, it is questionable whether it be right arbitrarily to reject days of one particular character. The point is one that occurs also in meteorology, and it is not usual in meteorological tabulations to omit days of abnormal character. In dealing with magnetic records there is, however, this difficulty—that the abnormal variations are at times of such magnitude as to defy treatment in the ordinary way. And between these occasional outbursts and the days of quiet magnetism intermediate degrees of intensity at different times occur. The arbitrary exclusion, to any considerable extent, of days other than those of extreme disturbance necessarily omits a certain portion of the diurnal phenomena, since the diurnal movement as a whole is a combination of the ordinary diurnal march with disturbance occurring apparently in an unexpected or accidental manner that appears to some extent to have also a local character. It having, however, become desirable to frame some method of comparing together the diurnal inequalities of magnetism at the different British magnetic observatories, at some of which it was inconvenient to undertake any great amount of tabulation of records, this circumstance led to the proposal to tabulate the curves for five days of quiet magnetism only in each month, the selection of days being made by the Astronomer Royal. This convention excludes entirely the influence of seemingly irregular magnetic disturbance. But it furnishes diurnal inequalities for the different observatories that are strictly comparable, and, depending entirely on days of quiet magnetism, they represent the undisturbed local diurnal variation.

In the Report of the Committee for the year 1895, Dr. Chree discussed at some length the results for Kew for the years 1890 to 1894, as found from the five selected quiet days in each month. In the same Report he drew attention also to an effect which, influencing only to a small extent and producing no real inconvenience in diurnal inequalities depending on all days of the month, in which also days of different character become combined, became very pronounced in the five day results, because of the small number of days employed and their restriction to days of one kind, those of quiet magnetism. The effect in question is the non-cyclic character of the resulting diurnal inequality, which in horizontal force he found to be such as to cause the value at the terminating midnight to be persistently greater than at the commencing midnight. And in the Report for 1896 Dr. Chree discussed the matter at greater length.

My present object may be said to be to discuss to some extent the five day results for Greenwich, in order to make comparison with results that Dr. Chree has found for Kew, and also to compare for Greenwich alone the diurnal inequalities and diurnal ranges as found from the five day tabulation with those given by the ordinary Greenwich tabulation, in which only days of extreme disturbance are omitted. When the all day tabulation is spoken of, it will be understood as implying the omission of days of extreme disturbance. The five day tabulation will be indifferently distinguished thus, or as the quiet day tabulation. I propose to consider first the comparison of Greenwich results.

To avoid lengthened titles to the various appended tables, I would first remark that the Greenwich results are all founded on mean results for the individual months of each year, these being combined in the different tables by months (that is, grouping together the same month in different years), or in quarters, or years, as necessary. Thus, in Table I. the results for each month depend on twenty-five days (five in each of the five years combined), and the quarters on seventy-five days, and so on. In the tabulation by quarters, first quarter is to be understood as comprising the months of January, February and March, and second quarter those of April, May, and June, and so on. In the seasonal tabulation, Spring is to be understood as including the months of February, March, and April, and Summer those of May, June, and July, and so on.

The values for declination are given in minutes of arc; those for horizontal and vertical force are throughout in c.g.s. measure $\times 10^6$, excepting in Table V., in which they are in c.g.s. measure $\times 10^5$. The approximate absolute value of horizontal force at Greenwich for the period treated is 0·183 c.g.s. and of vertical force 0·437 c.g.s., and nearly the same at Kew. To convert declination values in arc into westerly force in c.g.s. measure, to make comparison in the various tables with the numbers for horizontal and vertical force, multiply the minutes of arc by 53, excepting in Table V., for which the factor is 5·3. This it is convenient to remember for the ready estimation of the comparative magnitude of declination and horizontal and vertical force variations.[1]

In Tables I., II., and III., the Greenwich results for the years 1890 to 1894 have been combined to form mean monthly diurnal inequalities of declination and horizontal and vertical force, both for the all day tabulation and the quiet day tabulation, for comparison of the diurnal inequalities resulting from the two different methods of tabulation. The days omitted in the all day tabulation on account of extreme disturbance,

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[1] When horizontal and vertical force values are hereafter quoted in the text with the letters c.g.s. attached, they are to be understood, excepting for Table V., as indicating c.g.s. measure $\times 10^6$.

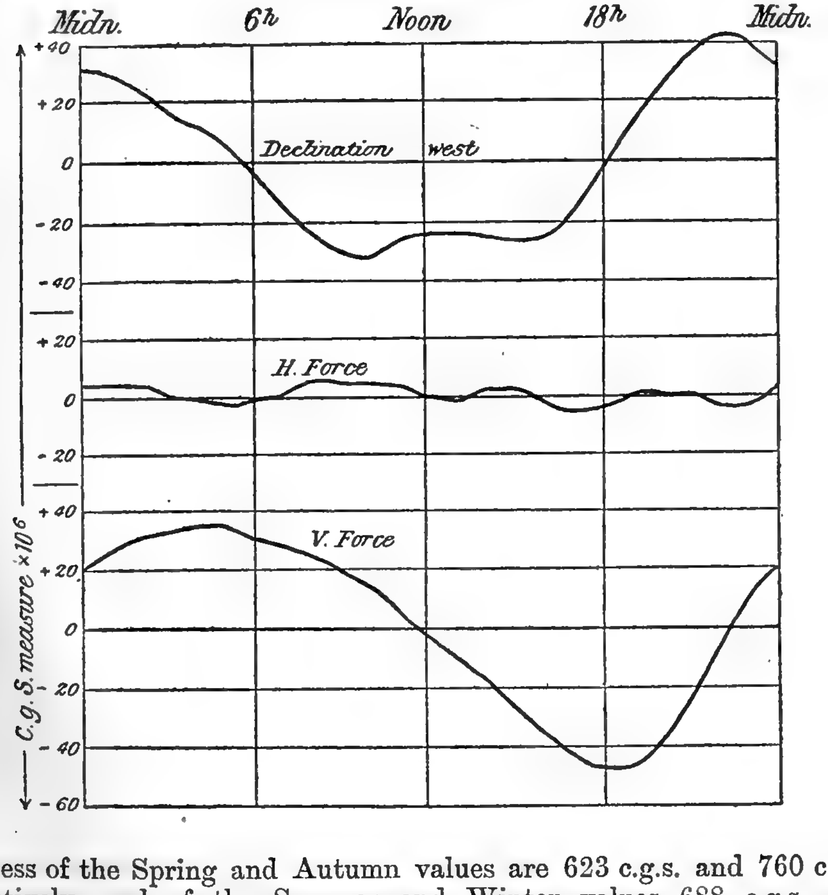
adding to the list those of the years 1889, 1895 and 1896, years that appear in subsequent tables, are as follows :—

1889. July 17, November 1.
1890. November 8.
1891. April 8, 12; May 14, 15, 16.
1892. January 4, 5, 6; February 13, 14; March 6, 12; April 25, 26; May 1, 2, 18, 19; June 2, 3, 27; July 12, 13, 14, 16, 17; August 12; November 4, 5; December 5.
1893. April 26; July 16; August 7, 18; November 2.
1894. February 23, 24, 25, 28; March 30, 31; July 20; August 20; September 15; November 13.
1895. None.
1896. None.

Regarding the selection of five days in each month for the quiet day tabulation, it should be explained that the days selected are really days of quiet magnetism, to which, until the end of the year 1893, I can personally testify. And further, the selection was made so as to bring the mean of days in each individual month as near to the middle of the month as possible. Occasionally, on account of the prevalence of magnetic disturbance, this condition could not be quite fulfilled. Still, in seventy-eight of the ninety-six individual months here treated, the mean of selected days comes within two days of the middle of the month; besides which, in combinations of months grouped together in different ways, the influence of deviation in this respect becomes greatly diminished, indeed, usually nearly neutralised or destroyed. Further, whenever quiet day values are compared, as the same quiet days are employed the question of dissimilarity of epoch disappears. It is only in the comparison of the Greenwich all day tabulation with the Greenwich five day tabulation in Tables I., II. and III., in the comparison of the Greenwich diurnal range of the all day tabulation with that of the quiet day tabulation in Table XI. (under columns *b–c*), and in Table XII., that the slight difference of epoch comes in. But the corrections required in these cases are so small, as compared with the magnitude of the variations and differences of elements exhibited, that it can scarcely be said to be worth attempting any correction, remembering further that, excepting in Table V., the figures are throughout carried one figure further than that of the actual tabulation. The effect on the values of Table XII. is the more important, and will be considered when speaking of that table.

In the quiet day results of Tables I., II., and III. the non-cyclic increment—that is, the algebraic excess of the terminal midnight value over that of the commencing midnight value—has been in each month eliminated by assuming in each element a uniform change through the twenty-four hours, and making correction accordingly. For the all day results no similar correction was needed. In the further tabulation of the two sets of numbers, they have been grouped by seasons in the way before mentioned, which represents more directly the seasonal effects than does the ordinary quarterly grouping, since neither the combination of the first three months of the year, nor of the last three months, gives due representation of the midwinter effect, March and October being both months having large diurnal inequalities. In declination, the values of hourly excess of quiet day value have, in the different seasonal periods, much the same character, but the Spring and Autumn numbers are, on the whole, numerically the larger. The sums of the twenty-four values of excess, taken without regard to sign, are in Spring and Autumn 13′·92 and 12′·97 respectively, and in Summer and Winter 7′·54 and 9′·34. The larger values thus occur in Spring and Autumn, periods of the year at which magnetic disturbance might more actively influence the all day values. In horizontal force the values of excess in the different seasons do not show such similarity as in declination; indeed, there is much discordance. Here the Spring and Autumn sums of excess are 247 c.g.s. and 280 c.g.s. respectively, and the Summer and Winter sums 210 c.g.s. and 260 c.g.s. In vertical force there is greater similarity in the values of excess at different seasons than in horizontal force: the sums of excess of the Spring and Autumn values are 623 c.g.s. and 760 c.g.s. respectively, and of the Summer and Winter values 688 c.g.s. and 408 c.g.s. The differences between the quiet day and all day diurnal inequalities for the year are shown in the annexed diagram, in which, for better estimation of comparative magnitude, the variations of declination are converted into variations of westerly force. It is curious to see how in horizontal force the opposite seasonal effects (in part probably accidental, rather than real) have tended so to neutralise each other that the resulting yearly curve appears to be an insignificant accidental residual.

Diurnal Inequality at Greenwich: Excess of quiet days ordinate above all days ordinate, 1890–1894.



The years 1890 to 1894 were selected for comparison of the Greenwich all day and quiet day diurnal inequalities because affording opportunity of also comparing the quiet day results with the corresponding Kew results for declination and horizontal force given in Tables III. and IV. of the 1895 B.A. Report. It seemed unnecessary here to make direct comparison of the monthly inequalities, and I have contented myself with extracting only the quarterly inequalities for Kew for comparison with the corresponding quarterly inequalities for Greenwich, formed by combining the months in the same way as at Kew. The differences between the two sets of quarterly numbers (see Table IV.) are not large; those of horizontal force are, however, the larger (1′ declination = 53 of the horizontal force unit of table).

It further seemed to be of interest to make direct comparison of diurnal inequality on quiet days for single months of some year at Greenwich and Kew. In Table V. this is done for the equinoctial and solstitial months of March, June, September, and December of the year 1894, the last for which the Greenwich results are published. The values are given as derived directly from observation, no correction for non-cyclic variation having been applied. Being single month results, depending each on five days only, the differences in declination may be considered to be on the whole small, excepting in September. In horizontal force and vertical force the agreement is not so good, and especially in June for horizontal force, and September and December for vertical force, remembering that here 1′ of declination corresponds to only 5 of the horizontal and vertical force unit of the table. The discordance in some months is mainly due to difference of the non-cyclic increment at the two places. The values in the several months are actually as follows:—

Non-cyclic Increment, Midnight to Midnight, 1894.

Month	Declination			Horizontal Force			Vertical Force		
	Greenwich	Kew	Excess of Kew	Greenwich	Kew	Excess of Kew	Greenwich	Kew	Excess of Kew
	′	′	′						
March	+0·1	+0·1	0·0	+2	+1	−1	+2	0	− 2
June	−1·0	−0·6	+0·4	+4	0	−4	−2	− 2	0
September	−0·2	+0·8	+1·0	−1	+3	+4	0	+14	+14
December	−0·2	−0·1	+0·1	−1	+1	+2	−9	+ 2	+11

The horizontal and vertical force values are here in c.g.s. measure × 10^5.

Thus in September in declination, and in September and December in vertical force, the difference between the values at the two places is large, amounting in vertical force to a considerable proportion of the whole diurnal movement. If corrected in these months for the non-cyclic increment, as locally observed, the diurnal inequalities would be brought more into accord.

In Table VI. further Greenwich declination and horizontal force quiet day results, derived from Tables I., II., and III., are compared with corresponding Kew results, as given in Table VIII. of the B.A. Report for 1895. The sums of the hourly values of diurnal inequality in declination and horizontal force, taken without regard to sign, also the diurnal range (difference between the least and greatest values in diurnal inequality), both as observed and after correction for non-cyclic variation, are the elements compared. The sums of hourly inequalities in declination are generally greater, and in horizontal force generally smaller at Kew than at Greenwich. In the comparison of diurnal range attention may be called to the comparatively small magnitude of the values of $a-b$, in declination, and their general similarity in different months at Greenwich and Kew. The corresponding values of $a-b$ in horizontal force are larger at both places, and larger at Greenwich than at Kew, but otherwise do not accord altogether badly. The diurnal range in declination as made cyclic is, on the whole, greater (column, K—G) at Kew than at Greenwich, on the average by $0'\cdot40=21$ of the horizontal force unit of the table, which is precisely the amount by which on the average the diurnal range in horizontal force, as made cyclic, is less at Kew than at Greenwich (column K—G for horizontal force). In this table the monthly sums of inequalities and monthly values of diurnal range are, for both places, necessarily derived from the respective monthly diurnal inequalities, but the quarterly and yearly values are formed directly from the monthly values (not from the quarterly and yearly values of diurnal inequality), the Kew numbers, with which the Greenwich numbers are compared, having been so formed. If derived from the quarterly and yearly diurnal inequalities, the numbers would have had a diminished value, since the grouping of monthly inequalities, in which the points of maximum and minimum vary somewhat in different months, necessarily flattens the curve to some extent. For the purpose of making comparison, either method would serve, but it must be similar at both places. The method adopted is the better one of the two.

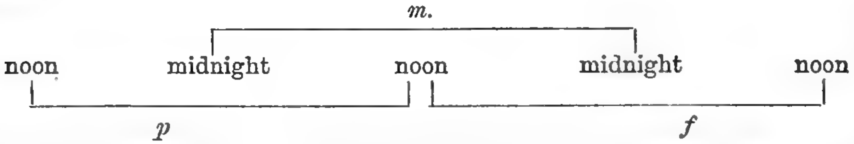
Table VII. contains a comparison of the mean non-cyclic increment on quiet days, in declination and horizontal and vertical force, at Greenwich and Kew, founded on the observations of the six years 1890 to 1895. The Kew numbers are those given in Table I. of the 1896 Report. The non-cyclic increment in declination and horizontal force is at the two places of the same character, both as regards variation of sign in declination in different months of the year and in the close correspondence in magnitude in horizontal force throughout the year. The individual months of positive and negative values are also very similar in number. In vertical force there is by no means the same accordance in value at the two places : in January the Kew value is 48 c.g.s. less than the Greenwich value, and in February 49 c.g.s. greater, and similar discordances occur in other months. The months of positive and negative values agree, however, in number better than, remarking the differences in value, might be expected. It may be here explained, with reference to all the tables that deal with the non-cyclic variation, Tables VII. to X., that the Greenwich values are not likely to be influenced by any incomplete correction for temperature. The diurnal range of temperature in the magnet basement (of which an automatic record is kept) is small, and the difference between the mean temperature of the successive midnights, or successive noons, both in the monthly and yearly grouping, never amounts to more than a small fraction of a degree. Further, the persistently large values in horizontal force in different months at Greenwich (Table VII.) are corroborated by the similarly large values observed at Kew.

It may be further noted that the character of the values of $a-b$, in Table VI., both in declination and horizontal force, is generally such as, considering the position of the points of maximum and minimum in the diurnal curve, the values of non-cyclic increment of Table VII. would produce.

Table VIII. gives further information as to the non-cyclic increment on quiet days in declination and horizontal and vertical force, as derived for Greenwich from the records of the eight years 1889 to 1896, combining not only the months of the different years to form mean monthly values, but giving also values for the separate years. The mean values for months, except in January and February for declination, are on the whole very similar to those of Table VII., which includes six of the years here employed. The greatest and least mean values of non-cyclic increment in individual months are here added, both for the monthly grouping and the yearly grouping. The mean of the differences between the greatest and least values differs for the mean of months from that for the mean of years in each element, since in the two groupings the extreme values combine in a different way. The mean for years is the larger, but this may have no significance, since the monthly differences depend on extremes selected from eight months only, whilst the yearly differences depend on selection from twelve months.

Table IX. contains a comparison of the annual values of the non-cyclic increment at Greenwich for declination and horizontal and vertical force, as appearing in Table VIII., with the corresponding annual values for Kew, as given in Table III. of the B.A. Report for 1896. The years are those on which the Kew values for months given in Table VII. are founded.

At the conclusion of the Report for the year 1896, Dr. Chree suggested that considerable light might be thrown on the question of the uniformity or variability of the non-cyclic element throughout the day by measurement of the curves for the noons preceding and succeeding each selected quiet day. As such measurement of the Greenwich curves had been made in the ordinary Greenwich tabulation, it appeared to be desirable to employ them for the suggested purpose, for which the Astronomer Royal kindly gave me the necessary permission. The grouping of these noon values, and, in the case of horizontal and vertical force, their correction for temperature, proved, however, to be a much heavier work than I had anticipated. An abstract of the results arrived at is given in Table X. The succeeding epochs alternately of noon and midnight being:—



the middle midnight to midnight increment $=m$ in Table X. is that of the selected quiet days as appearing in Table VIII.; $p=$ the increment from the preceding noon to the middle noon, and $f=$ that from the middle noon to the following noon. The last twelve hours of p and the first twelve hours of f thus together comprise the middle interval from midnight to midnight of the selected quiet day. Care was taken to see that the added initial and terminal half days introduced no vitiating element of disturbance. For uniform variation of the non-cyclic increment, m would be equal to the mean of p and $f=n$ in the table, as, for instance, in declination in October. Thus, positive values of $m-n$ indicate excess of the non-cyclic increment in the midnight to midnight interval. There is apparently considerable variation of value in each element in different months, but, taking the elements separately, a certain order appears. In declination there are nine months in which the values of p, m and f successively increase; these are January to April, June and July, and October to December. And the value of p is in ten months of the year negative, whilst that of f is in eleven months positive. Thus it would appear that the selected quiet days on the whole fall at a time of transition from a negative to a positive non-cyclic increment, indicating change from a decreasing to an increasing value of declination, represented in the general mean by values of $p = -0'\cdot26$, $m = -0'\cdot02$, and $f = +0'\cdot30$.

In horizontal force there are three months in which the values of p, m and f successively increase in value; these are April, July and August; and there are four months in which the values successively decrease; these are January, March, May and December. In the remaining five months—February, June, September, October and November—the value of m is greater than those either of p or f, which may indicate a turning-point in the value of the element. But there is altogether a preponderance of positive values, showing that the selected quiet days, on the whole, distinctly fall at times of increasing horizontal force.

In vertical force there are three months in which the values of p, m and f successively increase—these are March, May and October; and there are two months in which they successively decrease—these are February and June. There are five months—January, April, July, August and September—in which the value of m is greater than those of either p or f, and two months—November and December—in which the value of m is less than those of either p or f, which again may indicate turning-points in the value of the element. There is, however, an entire preponderance of negative values, showing that the selected quiet days fall altogether at times of decreasing vertical force.

All this, it will be understood, refers only to Greenwich. Further, if the cases of progressive increase and progressive decrease of value of non-cyclic variation (that is of the values of p, m and f in Table X.) of which there are nine months out of twelve in declination, seven months out of twelve in horizontal force, and five months out of twelve in vertical force, can be taken as representing a real condition of things, and are not due to any haphazard circumstances, it would justify to a certain extent the custom of making quiet day non-cyclic diurnal inequalities cyclic, by assuming uniform increase or decrease of the non-cyclic element through the twenty-four hours.

The values of p, m and f in Table X. for years support generally the conclusions derived from the values for months.

In Table XI. comparison of diurnal range in declination and horizontal and vertical force, as variously determined, is made for Greenwich, employing the results for the eight years 1889 to 1896. It is compared as found from the quiet day results (both as observed and corrected for non-cyclic variation) and from the all day results (which require no non-cyclic correction). The differences between the observed and corrected quiet day ranges, $a-b$, are generally small in declination and vertical force, but in horizontal force they are larger. As regards declination and horizontal force they have much the same order of magnitude as those for Greenwich appearing in Table VI. (in the comparison for a smaller number of years with Kew). In the comparison of diurnal range found from quiet days made cyclic, and from all days, $b-c$, the greatest and least monthly values are given for each element, both as referred to months and years. As in Table VIII., the mean of the differences between the greatest and least values differs for the mean for months from that for the mean for years in all elements, in regard to which the remarks made in speaking of Table VIII. apply also here.

The mean values of $b-c$ are most marked in declination in winter, and in horizontal and vertical force towards or in summer. The deviations between values of diurnal range, however determined, whether from quiet days as observed, or made cyclic, or from all days, are in a sense small as compared with the annual march of each element from its winter value to its greatly increased summer value, and back again to winter value. In the grouping for years the values of $b-c$ for vertical force show a progression from year to year for which there seems to be no sufficient explanation. The mean diurnal ranges of this table are throughout combinations of the diurnal ranges for individual months, formed from the monthly tables of diurnal inequality, not from combinations of diurnal inequalities for longer periods.

Table XII. contains for Greenwich the results of a determination of the difference between the absolute values of declination and horizontal and vertical force as found from all days and from quiet days in the years 1889 to 1896, combining the same month in different years for monthly differences, and giving also differences for separate years. The quiet day mean was found by selecting, for the several quiet days in each month, the daily means in declination and horizontal and vertical force from Tables I., III., and VII. of the Greenwich annual volumes, and comparing the respective monthly means of the same with the monthly means for all days taken from the Greenwich Table XI. Our table thus gives differences only—the excess of the quiet day value over the all day value. In addition to the mean excess of absolute value, there is given for each element also the greatest and least monthly values of excess, both for the monthly grouping and the yearly grouping. The mean excess in declination shows that the quiet day value was slightly greater than the all day value in nine months of the year, although the numbers in the column 'Least monthly excess' show that in each month the quiet day value was in some years in defect. In horizontal force the mean excess shows that the quiet day value was greater than the all day value in all months—in some considerably so—although in eleven months of the year the quiet day value was in some years in defect. In vertical force the mean excess shows that the quiet day value was less than the all day value in nine months of the year, although in each month the quiet day value was in some years in excess. The mean of the monthly numbers in the column 'Difference' is less than that of the yearly numbers, in all elements, as was found under similar conditions in Tables VIII. and XI.

In regard to the circumstance that the mean day of the five selected quiet days does not always fall exactly at the middle of the month, and the influence that this may have on the quiet day value, and consequently on the numbers of Table XII., it is to be remarked that in the monthly grouping eight months of different years are combined, and in the yearly grouping of course the twelve months of each year. And in neither of these groupings does the mean day resulting from the combination of months in any case differ by more than one day and a quarter from the middle of the month. Taking the annual decrease of declination as 6′·0, the increase of horizontal force as 180 c.g.s., and the decrease of vertical force as 80 c.g.s., the correction required to reduce the quiet day value to the middle of the month, that is the correction to the 'Mean excess' in the respective columns of the table, would thus never exceed about the $\frac{1}{300}$ part of the several annual variations above mentioned, and so may be here disregarded. Neither would the numbers in the columns of greatest and least monthly excess be sensibly affected.

The following comparison, referring to Greenwich, may be of interest :—

	Declination	Horizontal Force	Vertical Force
Mean value of non-cyclic element on quiet days. Table X.	−0′·02 = −1 c.g.s.	+39 c.g.s.	−17 c.g.s.
Mean excess of quiet day absolute value above the all day absolute value. Table XII.	+0′·08 = +4 c.g.s.	+33 c.g.s.	− 9 c.g.s.

In Sections 4 to 6 of the B.A. Report for 1896, Dr. Chree gave for the various magnetic elements the excess of Wild's normal day absolute value above the all day absolute value for St. Petersburg and Pawlowsk as taken from Dr. Müller's paper in Vol. 12 of the 'Repertorium für Meteorologie' and from the 'Annals of the Central Physical Observatory' respectively. Wild's normal days correspond generally in character with the Greenwich selected quiet days. I have therefore compared the results mentioned with the excess of the Greenwich quiet day absolute value above the Greenwich all day absolute value, as follows :—

Excess of Absolute Values of Magnetic Elements on Normal or Quiet Days above the Values for All Days.

Years	Declination west		Horizontal Force		Vertical Force	
	St. Petersburg	Greenwich	St. Petersburg	Greenwich	St. Petersburg	Greenwich
For years preceding 1885	+0′·25	—	+35	—	−8	—
1889–1896 . .	—	+0′·08	—	+33	—	− 9
	Pawlowsk		Pawlowsk		Pawlowsk	
1893 . . .	+0·3	+0·19	+40	+36	−30	−14
1894 . . .	+0·6	+0·12	+60	+53	−10	+14

The horizontal and vertical force values are in c.g.s. measure × 10^6.

The agreement in declination and horizontal force is on the whole satisfactory, although the +0′·6 for Pawlowsk in 1894 seems large. In vertical force the agreement is not so good ; the −30 at Pawlowsk in 1893 seems to diverge as much in the negative direction as does the +14 at Greenwich in 1894 in the positive direction.

It appears that in the years 1895 and 1896 the introduction of iron in the construction of new buildings at Greenwich affected to some extent the determination of absolute values, but the differential results here employed would not be sensibly influenced thereby. A new magnet pavilion is in course of erection in Greenwich Park, in a position apparently free from disturbing effect, to which the instruments will be removed.

TABLE I.—*Diurnal Inequality of Declination from*

Hour	Midn.	1	2	3	4	5	6	7	8	9	10
Including all days excepting those											
January	−1′·83	−1′·50	−1′·07	−0′·64	−0′·53	−0′·52	−0′·61	−0′·64	−0′·87	−0′·88	−0′·03
February	−2·25	−2·06	−1·62	−1·34	−1·09	−1·12	−1·14	−1·02	−1·15	−1·16	−0·12
March	−2·07	−1·92	−1·67	−1·62	−1·65	−1·60	−1·67	−2·26	−2·97	−2·64	−0·69
April	−1·42	−1·41	−1·38	−1·51	−1·79	−1·90	−2·57	−3·60	−4·41	−3·79	−1·44
May	−1·31	−1·50	−1·67	−1·86	−2·34	−3·29	−4·12	−4·65	−4·30	−2·92	−0·31
June	−0·89	−1·26	−1·43	−1·52	−2·29	−3·68	−4·69	−4·98	−4·73	−3·46	−1·11
July	−1·18	−1·07	−1·35	−1·67	−2·48	−3·71	−4·71	−4·93	−4·54	−3·37	−1·21
August	−1·22	−1·53	−1·73	−1·91	−2·27	−3·03	−3·96	−4·43	−4·03	−2·51	+0·15
September	−1·73	−2·06	−2·22	−2·38	−2·26	−2·32	−2·75	−3·12	−2·86	−1·54	+1·12
October	−1·98	−1·70	−1·58	−1·46	−1·18	−0·84	−0·82	−1·32	−2·14	−2.08	−0·50
November	−2·06	−1·45	−0 87	−0·69	−0·60	−0·69	−0·59	−0·55	−1·00	−1·17	−0·13
December	−1·95	−1·44	−0·97	−0·60	−0·50	−0·39	−0·36	−0·39	−0·48	−0·64	+0·01
Spring	−1·91	−1·80	−1·56	−1·49	−1·51	−1·54	−1·79	−2·29	−2·84	−2·53	−0·75
Summer	−1·13	−1·28	−1·48	−1·68	−2·37	−3·56	−4·51	−4·85	−4·52	−3·25	−0·88
Autumn	−1·64	−1·76	−1·84	−1·92	−1·90	−2·06	−2·51	−2·96	−3·01	−2·04	+0·26
Winter	−1·95	−1·46	−0·97	−0·64	−0·54	−0·53	−0·52	−0·53	−0·78	−0·90	−0·05
The Year	−1·66	−1·58	−1·46	−1·43	−1·58	−1·92	−2·33	−2·66	−2·79	−2·18	−0·36
From five selected quiet days in each month											
January	−1·36	−1·13	−0·83	−0·61	−0·67	−0·55	−0·75	−0·91	−1·21	−1·37	−0·45
February	−1·57	−1·52	−1·33	−1·20	−0·96	−0·99	−1·02	−1·17	−1·50	−1·66	−0·81
March	−1·07	−0·90	−0·74	−1·01	−1·20	−1·12	−1·57	−2·48	−3·64	−3·31	−1·52
April	−0·69	−0·67	−0·79	−1·05	−1·17	−1·49	−2·29	−3·63	−4·71	−4·27	−2·35
May	−0·83	−0·90	−1·10	−1·41	−2·12	−3·18	−4·27	−5·00	−4·66	−3·31	−0·48
June	−0·49	−0·72	−0·92	−1·16	−1·97	−3·32	−4·72	−5·12	−5·03	−3·74	−1·52
July	−0·65	−0·82	−1·16	−1·34	−2·00	−3·40	−4·53	−4·74	−4·84	−3·86	−1·66
August	−0·92	−1·15	−1·28	−1·67	−2·00	−2·93	−3·98	−4·71	−4·44	−3·01	−0·22
September	−1·16	−1·27	−1·47	−1·99	−2·22	−2·49	−3·13	−3·79	−3·66	−2·31	+0·35
October	−1·51	−1·16	−1·11	−1·02	−0·94	−1·19	−1·38	−1·93	−2·90	−3·02	−1·55
November	−1·21	−0·82	−0·75	−0·68	−0·53	−0·72	−0·97	−1·20	−1·75	−1·90	−0·77
December	−1·17	−0·80	−0·46	−0·31	−0·36	−0·52	−0·77	−0·80	−0·92	−1·09	−0·30
Spring	−1·11	−1·03	−0·95	−1·09	−1·11	−1·20	−1·63	−2·43	−3·28	−3·08	−1·56
Summer	−0·66	−0·81	−1·06	−1·30	−2·03	−3·30	−4·51	−4·95	−4·84	−3·64	−1·22
Autumn	−1·20	−1·19	−1·29	−1·56	−1·72	−2·20	−2·83	−3·48	−3·67	−2·78	−0·47
Winter	−1·25	−0·92	−0·68	−0·53	−0·52	−0·60	−0·83	−0·97	−1·29	−1·45	−0·51
The Year	−1·05	−0·99	−0·99	−1·12	−1·35	−1·82	−2·45	−2·96	−3·27	−2·74	−0·94
Excess of the quiet days value											
Spring	+0·80	+0·77	+0·61	+0·40	+0·40	+0·34	+0·16	−0·14	−0·44	−0·55	−0·81
Summer	+0·47	+0·47	+0·42	+0·38	+0·34	+0·26	0·00	−0·10	−0·32	−0·39	−0·34
Autumn	+0·44	+0·57	+0·55	+0·36	+0·18	−0·14	−0·32	−0·52	−0·66	−0·74	−0·73
Winter	+0·70	+0·54	+0·29	+0·11	+0·02	−0·07	−0·31	−0·44	−0·51	−0·55	−0·46
The Year	+0·61	+0·59	+0·47	+0·31	+0·23	+0·10	−0·12	−0·30	−0·48	−0·56	−0·58

Observations made at the Royal Observatory, Greenwich, 1890–1894.

11	Noon	13	14	15	16	17	18	19	20	21	22	23
of extreme magnetic disturbance.												
+1′·28	+2′·61	+3′·40	+2′·97	+2′·10	+1′·43	+0′·92	+0′·45	−0′·12	−0′·85	−1′·44	−1′·77	−1′·86
+1·78	+3·61	+4·44	+4·38	+3·22	+1·91	+0·90	+0·32	−0·10	−0·77	−1·46	−1·92	−2·24
+2·30	+5·21	+6·42	+6·05	+4·68	+2·61	+0·86	−0·05	−0·66	−1·11	−1·62	−1·85	−2·08
+1·99	+5·34	+6·93	+6·54	+4·85	+3·11	+1·44	+0·19	−0·56	−0·91	−1·05	−1·24	−1·41
+2·84	+5·37	+6·42	+6·03	+4·82	+3·20	+1·87	+0·68	−0·05	−0·40	−0·66	−0·81	−1·04
+1·80	+4·35	+5·70	+5·99	+5·20	+3·79	+2·30	+1·19	+0·38	+0·07	−0·08	−0·15	−0·50
+1·83	+4·72	+6·13	+6·39	+5·33	+3·76	+2·23	+0·93	+0·27	0·00	−0·27	−0·41	−0·69
+3·17	+5·98	+6·93	+6·27	+4·63	+2·47	+0·79	−0·16	−0·41	−0·55	−0·61	−0·97	−1·07
+4·02	+5·95	+6·64	+5·70	+4·00	+2·10	+0·72	−0·15	−0·68	−1·32	−1·42	−1·54	−1·90
+2·46	+4·92	+5·78	+5·28	+3·84	+2·18	+0·82	−0·06	−0·72	−1·60	−2·30	−2·56	−2·44
+1·85	+3·50	+4·13	+3·57	+2·47	+1·48	+0·75	+0·13	−0·53	−1·34	−1·87	−2·11	−2·23
+1·32	+2·39	+3·04	+2·89	+2·30	+1·56	+0·97	+0·46	−0·17	−1·06	−1·78	−2·05	−2·16
+2·02	+4·72	+5·93	+5·66	+4·25	+2·54	+1·07	+0·15	−0·44	−0·93	−1·38	−1·67	−1·91
+2·16	+4·81	+6·08	+6·14	+5·12	+3·58	+2·13	+0·93	+0·20	−0·11	−0·34	−0·46	−0·74
+3·22	+5·62	+6·45	+5·75	+4·16	+2·25	+0·78	−0·12	−0·60	−1·16	−1·44	−1·69	−1·80
+1·48	+2·83	+3·52	+3·14	+2·29	+1·49	+0·88	+0·35	−0·27	−1·08	−1·70	−1·98	−2·08
+2·22	+4·50	+5·50	+5·17	+3·95	+2·47	+1·21	+0·33	−0·28	−0·82	−1·21	−1·45	−1·64
after elimination of the non-cyclic increment.												
+0·87	+2·52	+3·37	+2·91	+1·89	+1·23	+0·83	+0·49	+0·01	−0·59	−0·97	−1·31	−1·41
+1·18	+2·93	+3·66	+3·75	+2·80	+1·44	+0·73	+0·58	+0·21	−0·30	−0·80	−1·07	−1·38
+1·70	+4·57	+5·72	+5·22	+3·67	+1·60	+0·32	−0·09	−0·48	−0·64	−0·91	−1·02	−1·10
+1·11	+4·23	+6·05	+5·49	+3·93	+2·33	+1·05	+0·15	−0·21	−0·19	−0·05	−0·27	−0·51
+2·86	+5·75	+6·62	+6·08	+4·27	+2·40	+0·98	+0·05	−0·30	−0·44	−0·41	−0·22	−0·38
+1·44	+4·31	+5·64	+5·62	+4·58	+3·23	+1·90	+1·04	+0·42	+0·29	+0·30	+0·24	−0·30
+1·30	+4·33	+6·04	+6·52	+5·32	+3·32	+1·44	+0·45	+0·08	+0·14	+0·10	+0·06	−0·10
+3·07	+5·90	+6·77	+5·96	+4·27	+2·18	+0·41	−0·34	−0·13	−0·28	−0·31	−0·52	−0·67
+3·41	+5·38	+5·77	+4·95	+3·13	+1·52	+0·53	+0·05	−0·05	−0·36	−0·31	−0·27	−0·61
+1·38	+3·87	+4·92	+4·69	+3·42	+1·88	+1·11	+0·52	+0·05	−0·38	−1·04	−1·25	−1·46
+1·28	+3·11	+3·68	+3·07	+2·10	+1·29	+0·62	+0·31	−0·10	−0·57	−1·00	−1·19	−1·30
+0·98	+1·87	+2·52	+2·38	+1·79	+1·04	+0·52	+0·31	−0·02	−0·46	−0·91	−1·24	−1·28
+1·33	+3·91	+5·14	+4·82	+3·47	+1·79	+0·70	+0·21	−0·16	−0·38	−0·59	−0·79	−1·00
+1·87	+4·80	+6·10	+6·07	+4·72	+2·98	+1·44	+0·51	+0·07	0·00	0·00	+0·03	−0·26
+2·62	+5·05	+5·82	+5·20	+3·61	+1·86	+0·68	+0·08	−0·04	−0·34	−0·55	−0·68	−0·91
+1·04	+2·50	+3·19	+2·79	+1·93	+1·19	+0·66	+0·37	−0·04	−0·54	−0·96	−1·25	−1·33
+1·72	+4·06	+5·06	+4·72	+3·43	+1·96	+0·87	+0·29	−0·04	−0·32	−0·53	−0·67	−0·87
above the all days value.												
−0·69	−0·81	−0·79	−0·84	−0·78	−0·75	−0·37	+0·06	+0·28	+0·55	+0·79	+0·88	+0·91
−0·29	−0·01	+0·02	−0·07	−0·40	−0·60	−0·69	−0·42	−0·13	+0·11	+0·34	+0·49	+0·48
−0·60	−0·57	−0·63	−0·55	−0·55	−0·39	−0·10	+0·20	+0·56	+0·82	+0·89	+1·01	+0·89
−0·44	−0·33	−0·33	−0·35	−0·36	−0·30	−0·22	+0·02	+0·23	+0·54	+0·74	+0·73	+0·75
−0·50	−0·44	−0·44	−0·45	−0·52	−0·51	−0·34	−0·04	+0·24	+0·50	+0·68	+0·78	+0·77

TABLE II.—*Diurnal Inequality of Horizontal Force from*

Hour	Midn.	1	2	3	4	5	6	7	8	9	10
Including all days excepting those											
January . .	+ 4	+ 5	+ 9	+14	+33	+ 55	+57	+ 55	+ 21	− 39	− 96
February .	+ 33	+16	+ 3	+ 4	+15	+ 40	+54	+ 45	+ 7	− 68	−117
March . .	+ 45	+34	+32	+33	+28	+ 35	+36	+ 6	− 64	−160	−220
April . .	+ 90	+73	+45	+35	+24	+ 27	+11	− 35	−114	−222	−300
May . .	+ 67	+48	+28	+14	+ 1	− 25	−61	−127	−198	−245	−253
June . .	+ 66	+47	+30	+25	+17	− 18	−78	−155	−235	−287	−290
July . .	+ 65	+50	+35	+21	+ 8	− 18	−70	−141	−220	−281	−303
August . .	+ 95	+84	+59	+49	+38	+ 4	−54	−147	−248	−319	−322
September .	+100	+85	+76	+62	+51	+ 51	+ 7	− 61	−166	−241	−274
October . .	+ 83	+82	+78	+83	+89	+100	+86	+ 44	− 47	−172	−254
November .	+ 41	+35	+27	+37	+54	+ 70	+77	+ 65	+ 7	− 80	−147
December .	+ 5	+ 4	+ 4	+17	+35	+ 58	+73	+ 67	+ 51	− 9	− 65
Spring . .	+ 56	+41	+27	+24	+22	+ 34	+34	+ 5	− 57	−150	−212
Summer . .	+ 66	+48	+31	+20	+ 9	− 20	−70	−141	−218	−271	−282
Autumn . .	+ 93	+84	+71	+65	+59	+ 52	+13	− 55	−154	−244	−283
Winter . .	+ 17	+15	+13	+23	+41	+ 61	+69	+ 62	+ 26	− 43	−103
The Year .	+ 58	+47	+35	+33	+33	+ 32	+11	− 32	−101	−177	−220
From five selected quiet days in each month											
January . .	+ 12	+15	+17	+18	+40	+ 53	+55	+ 47	+ 17	− 43	− 94
February .	+ 45	+36	+16	+17	+20	+ 36	+39	+ 57	+ 17	− 59	−128
March . .	+ 69	+54	+43	+34	+24	+ 38	+42	+ 9	− 61	−163	−212
April . .	+ 86	+82	+62	+44	+42	+ 43	+33	− 4	− 82	−195	−275
May . .	+ 82	+61	+37	+22	0	− 19	−54	−133	−220	−275	−265
June . .	+ 72	+49	+37	+36	+18	− 14	−75	−151	−224	−276	−272
July . .	+ 78	+63	+39	+30	+24	0	−55	−110	−184	−253	−288
August . .	+ 90	+77	+68	+55	+51	+ 17	−33	−130	−221	−299	−308
September .	+101	+77	+64	+40	+35	+ 19	−29	−101	−183	−257	−263
October . .	+ 63	+60	+59	+66	+65	+ 73	+68	+ 37	− 35	−144	−225
November .	+ 39	+41	+37	+38	+56	+ 65	+75	+ 55	− 9	−102	−173
December .	− 5	−11	−14	− 6	+ 9	+ 25	+46	+ 44	+ 29	− 24	− 75
Spring . .	+ 67	+57	+40	+32	+29	+ 39	+38	+ 21	− 42	−139	−205
Summer . .	+ 77	+58	+38	+29	+14	− 11	−61	−131	−209	−268	−275
Autumn . .	+ 85	+71	+64	+54	+50	+ 36	+ 2	− 65	−146	−233	−265
Winter . .	+ 15	+15	+13	+17	+35	+ 48	+59	+ 49	+ 12	− 56	−114
The Year .	+ 61	+50	+39	+33	+32	+ 28	+ 9	− 32	− 96	−174	−215
Excess of the quiet days value											
Spring . .	+ 11	+16	+13	+ 8	+ 7	+ 5	+ 4	+ 16	+ 15	+ 11	+ 7
Summer . .	+ 11	+10	+ 7	+ 9	+ 5	+ 9	+ 9	+ 10	+ 9	+ 3	+ 7
Autumn . .	− 8	−13	− 7	−11	− 9	− 16	−11	− 10	+ 8	+ 11	+ 18
Winter . .	− 2	0	0	− 6	− 6	− 13	−10	− 13	− 14	− 13	− 11
The Year .	+ 3	+ 3	+ 4	0	− 1	− 4	− 2	0	+ 5	+ 3	+ 5

Observations made at the Royal Observatory, Greenwich, 1890–1894.

11	Noon	13	14	15	16	17	18	19	20	21	22	23
of extreme magnetic disturbance.												
−112	−92	−41	−8	+3	−5	+6	+22	+31	+28	+21	+13	+16
−139	−109	−64	−20	+15	+36	+36	+35	+37	+42	+39	+27	+33
−218	−153	−67	+7	+48	+54	+61	+77	+86	+90	+71	+66	+73
−297	−209	−111	−25	+45	+94	+118	+134	+143	+137	+124	+109	+104
−218	−146	−77	−7	+48	+106	+161	+199	+191	+167	+133	+105	+89
−245	−170	−84	+1	+79	+128	+178	+210	+220	+194	+154	+118	+95
−270	−177	−89	−2	+77	+127	+169	+210	+216	+199	+159	+129	+106
−271	−171	−60	+19	+69	+102	+127	+159	+180	+171	+162	+146	+128
−246	−133	−45	+8	+30	+33	+50	+83	+114	+113	+101	+103	+99
−260	−204	−123	−57	−17	−5	+24	+58	+72	+84	+88	+86	+82
−162	−128	−77	−44	−22	+3	+25	+31	+33	+33	+42	+42	+38
−97	−87	−55	−28	−18	−1	+8	+10	+14	+2	+3	+1	+8
−218	−157	−81	−13	+36	+61	+72	+82	+89	+90	+78	+67	+70
−244	−164	−83	−3	+68	+120	+169	+206	+209	+187	+149	+117	+97
−259	−169	−76	−10	+27	+43	+67	+100	+122	+123	+117	+112	+103
−124	−102	−58	−27	−12	−1	+13	+21	+26	+21	+22	+19	+21
−211	−148	−74	−13	+30	+56	+80	+102	+111	+105	+91	+79	+73
after elimination of the non-cyclic increment.												
−132	−108	−60	−19	−6	−2	+19	+35	+42	+41	+26	+14	+13
−158	−139	−96	−38	−7	+9	+27	+43	+56	+72	+55	+38	+42
−212	−161	−77	−8	+44	+38	+36	+60	+86	+84	+82	+73	+78
−276	−217	−132	−49	+26	+66	+89	+116	+129	+120	+107	+95	+90
−221	−144	−65	+8	+60	+120	+152	+174	+170	+150	+144	+119	+97
−243	−155	−80	+11	+94	+113	+146	+181	+201	+178	+142	+118	+94
−260	−189	−103	−11	+70	+122	+152	+176	+177	+168	+145	+113	+96
−262	−163	−60	+24	+78	+96	+106	+140	+168	+149	+138	+113	+106
−207	−83	+8	+51	+39	+28	+43	+80	+117	+118	+114	+94	+95
−238	−190	−99	−41	−8	+5	+36	+70	+81	+81	+72	+69	+75
−178	−154	−106	−46	−5	+23	+47	+58	+67	+61	+49	+32	+30
−95	−83	−47	−10	0	+21	+44	+36	+45	+36	+21	+6	+8
−215	−172	−102	−32	+21	+38	+51	+73	+90	+92	+81	+69	+70
−241	−163	−83	+3	+75	+118	+150	+177	+183	+165	+144	+117	+96
−236	−145	−50	+11	+36	+43	+62	+97	+122	+116	+108	+92	+92
−135	−115	−71	−25	−4	+14	+37	+43	+51	+46	+32	+17	+17
−207	−149	−76	−11	+32	+53	+75	+97	+112	+105	+91	+74	+69
above the all days value.												
+3	−15	−21	−19	−15	−23	−21	−9	+1	+2	+3	+2	0
+3	+1	0	+6	+7	−2	−19	−29	−26	−22	−5	0	−1
+23	+24	+26	+21	+9	0	−5	−3	0	−7	−9	−20	−11
−11	−13	−13	+2	+8	+15	+24	+22	+25	+25	+10	−2	−4
+4	−1	−2	+2	+2	−3	−5	−5	+1	0	0	−5	−4

TABLE III.—*Diurnal Inequality of Vertical Force from*

Hour	Midn.	1	2	3	4	5	6	7	8	9	10
											Including all days excepting those
January . .	−20	−25	−33	−34	−37	−33	−27	−18	−13	−22	− 21
February .	−15	−31	−38	−34	−29	−22	−26	−25	−10	−19	− 52
March . .	−33	−45	−48	−44	−41	−23	−17	+ 5	+12	−23	− 71
April . .	− 8	−28	−34	−32	−20	− 8	+ 8	+31	+22	− 29	− 91
May . .	+ 4	−14	−18	−16	+ 2	+14	+18	+11	−19	−78	−148
June . .	− 5	−15	−25	−21	− 4	+17	+18	+13	−17	−69	−120
July . .	−20	−40	−46	−37	−16	+11	+20	+17	− 2	−47	− 93
August . .	−20	−40	−43	−35	−19	+ 2	+19	+39	+28	−22	− 78
September .	−28	−44	−55	−62	−51	−45	−33	− 2	−10	−48	− 83
October . .	−28	−41	−52	−55	−59	−52	−42	−19	− 1	−14	− 47
November .	−18	−29	−42	−42	−42	−41	−35	−29	−20	−28	− 44
December .	−22	−34	−39	−36	−31	−20	−23	−12	− 7	−11	− 20
Spring . .	−19	−35	−40	−37	−30	−18	−12	+ 4	+ 8	−24	− 71
Summer . .	− 7	−23	−30	−25	− 6	+14	+19	+14	−13	−65	−120
Autumn . .	−25	−42	−50	−51	−43	−32	−19	+ 6	+ 6	−28	− 69
Winter . .	−20	−29	−38	−37	−37	−31	−28	−20	−13	−20	− 28
The Year .	−18	−32	−39	−37	−29	−17	−10	+ 1	− 3	−34	− 72
											From five selected quiet days in each month
January . .	−16	−21	−31	−25	−24	−22	−19	−10	+ 2	+ 3	+ 3
February .	− 7	−30	−35	−24	−10	+ 4	0	+ 2	+20	+ 7	− 22
March . .	+ 4	− 8	− 8	− 2	+ 5	+19	+19	+42	+36	−13	− 65
April . .	+ 9	+ 9	− 6	+ 7	+18	+27	+33	+59	+49	− 4	− 62
May . .	+24	+28	+23	+28	+43	+50	+48	+40	+ 6	−63	−139
June . .	+18	+10	+15	+13	+27	+47	+44	+39	+ 6	−57	−103
July . .	+17	+11	+ 4	+10	+30	+55	+51	+51	+21	−18	− 75
August . .	−14	−11	− 9	− 3	+ 7	+34	+43	+69	+58	− 4	− 60
September .	+23	+ 5	+ 7	+ 4	+11	+17	+18	+35	+12	−34	− 89
October . .	− 8	− 7	−14	−19	−20	−17	− 8	+ 6	+13	− 4	− 55
November .	−16	−19	−19	−21	−16	− 4	− 2	+ 3	+19	+12	− 16
December .	−24	−25	−23	−11	−11	+ 6	− 6	+ 8	+ 3	− 4	− 15
Spring . .	+ 2	−10	−16	− 6	+ 4	+17	+17	+34	+35	− 3	− 50
Summer . .	+20	+16	+14	+17	+33	+51	+48	+43	+11	−46	−106
Autumn . .	0	− 4	− 5	− 6	− 1	+11	+18	+37	+28	−14	− 68
Winter . .	−19	−22	−24	−19	−17	− 7	− 9	− 1	+ 8	+ 4	− 9
The Year .	+ 1	− 5	− 8	− 4	+ 5	+18	+18	+28	+20	−15	− 58
											Excess of the quiet days value
Spring . .	+21	+25	+24	+31	+34	+35	+29	+30	+27	+21	+ 21
Summer . .	+27	+39	+44	+42	+39	+37	+29	+29	+24	+19	+ 14
Autumn . .	+25	+38	+45	+45	+42	+43	+37	+31	+22	+14	+ 1
Winter . .	+ 1	+ 7	+14	+18	+20	+24	+19	+19	+21	+24	+ 19
The Year .	+19	+27	+31	+33	+34	+35	+28	+27	+23	+19	+ 14

Observations made at the Royal Observatory, Greenwich, 1890–1894.

of extreme magnetic disturbance.

11	Noon	13	14	15	16	17	18	19	20	21	22	23
−16	−26	−7	+27	+43	+53	+53	+50	+47	+37	+21	+7	−6
−61	−59	−32	+7	+48	+70	+75	+74	+69	+58	+37	+13	+2
−112	−117	−76	+11	+54	+101	+121	+112	+103	+78	+58	+28	−11
−150	−172	−132	−48	+23	+78	+118	+133	+120	+95	+70	+40	+14
−198	−198	−137	−59	+12	+73	+124	+156	+153	+126	+95	+64	+33
−169	−167	−116	−48	+12	+75	+118	+136	+134	+109	+76	+45	+23
−146	−153	−121	−51	+20	+77	+128	+144	+131	+99	+63	+45	+17
−124	−122	−84	−15	+51	+95	+109	+105	+82	+56	+29	+5	−18
−103	−102	−51	+17	+77	+119	+131	+122	+107	+85	+57	+17	−15
−78	−63	−23	+25	+82	+110	+107	+92	+84	+61	+36	+2	−25
−45	−28	+3	+41	+70	+82	+74	+68	+58	+43	+23	0	−19
−17	−5	+4	+27	+46	+52	+47	+42	+32	+26	+16	+1	−16
−108	−116	−80	−17	+42	+83	+105	+106	+97	+77	+55	+27	+2
−171	−173	−125	−53	+15	+75	+123	+145	+139	+111	+78	+51	+24
−102	−96	−53	+9	+70	+108	+116	+106	+91	+67	+41	+8	−19
−26	−20	0	+32	+53	+62	+58	+53	+46	+35	+20	+3	−14
−102	−101	−64	−7	+45	+82	+100	+103	+93	+73	+48	+22	−2

after elimination of the non-cyclic increment.

11	Noon	13	14	15	16	17	18	19	20	21	22	23
−7	−10	0	+25	+40	+38	+30	+28	+18	+15	−4	−8	−5
−38	−42	−23	−2	+32	+40	+38	+29	+18	+18	+13	+11	+1
−123	−146	−109	−45	+31	+70	+69	+63	+47	+45	+35	+23	+11
−132	−160	−136	−59	+6	+41	+60	+66	+59	+50	+34	+25	+7
−200	−213	−146	−61	−3	+54	+93	+106	+91	+70	+55	+35	+31
−168	−168	−123	−63	−10	+39	+71	+91	+84	+77	+46	+37	+28
−143	−179	−148	−74	−29	+31	+76	+88	+78	+56	+44	+26	+17
−109	−120	−93	−17	+25	+49	+59	+56	+32	+17	+10	−5	−14
−128	−129	−85	−37	+14	+40	+49	+50	+54	+55	+48	+33	+27
−89	−82	−55	−13	+32	+63	+61	+52	+49	+43	+33	+26	+13
−41	−27	−4	+28	+35	+32	+35	+21	+10	+9	−6	−8	−5
−11	−5	+9	+22	+29	+37	+31	+17	+13	0	−8	−8	−19
−98	−116	−89	−35	+23	+50	+56	+53	+41	+38	+27	+20	+6
−170	−187	−139	−66	−14	+41	+80	+95	+84	+68	+48	+33	+25
−109	−110	−78	−22	+24	+51	+56	+53	+45	+38	+30	+18	+9
−20	−14	+2	+25	+35	+36	+32	+22	+14	+8	−6	−8	−10
−99	−107	−76	−25	+17	+45	+56	+56	+46	+38	+25	+16	+8

above the all days value.

11	Noon	13	14	15	16	17	18	19	20	21	22	23
+10	0	−9	−18	−19	−33	−49	−53	−56	−39	−28	−7	+4
+1	−14	−14	−13	−29	−34	−43	−50	−55	−43	−30	−18	+1
−7	−14	−25	−31	−46	−57	−60	−53	−46	−29	−11	+10	+28
+6	+6	+2	−7	−18	−26	−26	−31	−32	−27	−26	−11	+4
+3	−6	−12	−18	−28	−37	−44	−47	−47	−35	−23	−6	+10

TABLE IV.—*Diurnal Inequality of Declination and Horizontal*

(After elimination of the

Hour	Midn.	1	2	3	4	5	6	7	8	9	10
						Declination,					
	′	′	′	′	′	′	′	′	′	′	′
First Quarter .	−1·33	−1·18	−0·97	−0·94	−0·94	−0·89	−1·11	−1·52	−2·12	−2·11	−0·93
Second Quarter	−0·67	−0·76	−0·94	−1·21	−1·75	−2·66	−3·76	−4·58	−4·80	−3·77	−1·45
Third Quarter .	−0·91	−1·08	−1·30	−1·67	−2·07	−2·94	−3·88	−4·41	−4·31	−3·06	−0·51
Fourth Quarter	−1·30	−0·93	−0·77	−0·67	−0·61	−0·81	−1·04	−1·31	−1·86	−2·00	−0·87
The Year. .	−1·05	−0·99	−0·99	−1·12	−1·35	−1·82	−2·45	−2·96	−3·27	−2·74	−0·94
						Declination,					
First Quarter .	−1·28	−1·18	−1·02	−0·97	−1·03	−1·09	−1·26	−1·67	−2·31	−2·26	−0·86
Second Quarter	−0·66	−0·78	−0·97	−1·23	−1·84	−2·89	−3·88	−4·74	−4·93	−3·84	−1·25
Third Quarter .	−0·99	−1·11	−1·34	−1·67	−2·18	−3·04	−3·95	−4·53	−4·48	−3·04	−0·29
Fourth Quarter	−1·26	−0·90	−0·76	−0·69	−0·75	−0·83	−1·12	−1·41	−1·97	−2·11	−0·86
The Year. .	−1·05	−1·00	−1·02	−1·14	−1·45	−1·96	−2·55	−3·09	−3·42	−2·81	−0·82
						Excess of Declination					
First Quarter .	+0·05	0·00	−0·05	−0·03	−0·09	−0·20	−0·15	−0·15	−0·19	−0·15	+0·07
Second Quarter	+0·01	−0·02	−0·03	−0·02	−0·09	−0·23	−0·12	−0·16	−0·13	−0·07	+0·20
Third Quarter .	−0·08	−0·03	−0·04	0·00	−0·11	−0·10	−0·07	−0·12	−0·17	+0·02	+0·22
Fourth Quarter	+0·04	+0·03	+0·01	−0·02	−0·14	−0·02	−0·08	−0·10	−0·11	−0·11	+0·01
The Year. .	0·00	−0·01	−0·03	−0·02	−0·10	−0·14	−0·10	−0·13	−0·15	−0·07	+0·12
						Horizontal Force,					
First Quarter .	+ 42	+ 35	+ 25	+ 23	+ 28	+ 42	+ 45	+ 38	− 9	− 88	− 145
Second Quarter	+ 80	+ 64	+ 45	+ 34	+ 20	+ 3	− 32	− 96	− 175	− 249	− 271
Third Quarter .	+ 90	+ 72	+ 57	+ 42	+ 37	+ 12	− 39	− 114	− 196	− 270	− 286
Fourth Quarter	+ 32	+ 30	+ 27	+ 33	+ 43	+ 54	+ 63	+ 45	− 5	− 90	− 158
The Year. .	+ 61	+ 50	+ 39	+ 33	+ 32	+ 28	+ 9	− 32	− 96	− 174	− 215
						Horizontal Force,					
First Quarter .	+ 34	+ 26	+ 25	+ 26	+ 36	+ 56	+ 59	+ 55	+ 12	− 65	− 127
Second Quarter	+ 74	+ 66	+ 53	+ 52	+ 43	+ 34	− 1	− 56	− 139	− 216	− 258
Third Quarter .	+ 75	+ 74	+ 59	+ 57	+ 49	+ 30	− 14	− 82	− 166	− 242	− 277
Fourth Quarter	+ 29	+ 28	+ 30	+ 40	+ 53	+ 68	+ 74	+ 57	+ 10	− 70	− 145
The Year. .	+ 53	+ 49	+ 42	+ 44	+ 45	+ 47	+ 29	− 6	− 71	− 148	− 202
						Excess of Horizontal Force					
First Quarter .	− 8	− 9	0	+ 3	+ 8	+ 14	+ 14	+ 17	+ 21	+ 23	+ 18
Second Quarter	− 6	+ 2	+ 8	+ 18	+ 23	+ 31	+ 31	+ 40	+ 36	+ 33	+ 13
Third Quarter .	− 15	+ 2	+ 2	+ 15	+ 12	+ 18	+ 25	+ 32	+ 30	+ 28	+ 9
Fourth Quarter	− 3	− 2	+ 3	+ 7	+ 10	+ 14	+ 11	+ 12	+ 15	+ 20	+ 13
The Year. .	− 8	− 1	+ 3	+ 11	+ 13	+ 19	+ 20	+ 26	+ 25	+ 26	+ 13

Force at Greenwich and Kew on Quiet Days, 1890–1894, *compared.*

non-cyclic increment.)

11	Noon	13	14	15	16	17	18	19	20	21	22	23
						Greenwich.						
′	′	′	′	′	′	′	′	′	′	′	′	′
+1·25	+3·34	+4·25	+3·96	+2·79	+1·42	+0·63	+0·33	−0·09	−0·51	−0·89	−1·13	−1·30
+1·80	+4·76	+6·10	+5·73	+4·26	+2·65	+1·31	+0·41	−0·03	−0·11	−0·05	−0·08	−0·40
+2·59	+5·20	+6·19	+5·81	+4·24	+2·34	+0·79	+0·05	−0·03	−0·17	−0·17	−0·24	−0·46
+1·21	+2·95	+3·71	+3·38	+2·44	+1·40	+0·75	+0·38	−0·02	−0·47	−0·98	−1·23	−1·35
+1·72	+4·06	+5·06	+4·72	+3·43	+1·96	+0·87	+0·29	−0·04	−0·32	−0·53	−0·67	−0·87
						Kew.						
+1·29	+3·45	+4·42	+4·10	+2·97	+1·53	+0·67	+0·29	−0·08	−0·48	−0·89	−1·10	−1·25
+1·95	+4·99	+6·39	+5·94	+4·42	+2·69	+1·24	+0·33	−0·11	−0·18	−0·13	−0·11	−0·40
+2·84	+5·54	+6·62	+6·07	+4·41	+2·34	+0·71	−0·07	−0·19	−0·31	−0·28	−0·41	−0·64
+1·30	+3·10	+3·96	+3·51	+2·57	+1·49	+0·75	+0·34	−0·06	−0·56	−1·08	−1·31	−1·34
+1·84	+4·27	+5·35	+4·90	+3·59	+2·01	+0·84	+0·22	−0·11	−0·38	−0·60	−0·73	−0·91
						at Kew.						
+0·04	+0·11	+0·17	+0·14	+0·18	+0·11	+0·04	−0·04	+0·01	+0·03	0·00	+0·03	+0·05
+0·15	+0·23	+0·29	+0·21	+0·16	+0·04	−0·07	−0·08	−0·08	−0·07	−0·08	−0·03	0·00
+0·25	+0·34	+0·43	+0·26	+0·17	0·00	−0·08	−0·12	−0·16	−0·14	−0·11	−0·17	−0·18
+0·09	+0·15	+0·25	+0·13	+0·13	+0·09	0·00	−0·04	−0·04	−0·09	−0·10	−0·08	+0·01
+0·12	+0·21	+0·29	+0·18	+0·16	+0·05	−0·03	−0·07	−0·07	−0·06	−0·07	−0·06	−0·04
						Greenwich.						
−167	−136	− 78	− 22	+ 10	+ 15	+ 27	+ 46	+ 61	+ 66	+ 54	+ 42	+ 44
−247	−172	− 92	− 10	+ 60	+100	+129	+157	+167	+149	+131	+111	+ 94
−243	−145	− 52	+ 21	+ 62	+ 82	+100	+132	+154	+146	+132	+107	+ 99
−170	−142	− 84	− 32	− 4	+ 16	+ 42	+ 55	+ 64	+ 59	+ 47	+ 36	+ 38
−207	−149	− 76	− 11	+ 32	+ 53	+ 75	+ 97	+112	+105	+ 91	+ 74	+ 69
						Kew.						
−155	−128	− 74	− 31	− 4	+ 2	+ 9	+ 35	+ 50	+ 49	+ 42	+ 33	+ 35
−244	−176	−104	− 32	+ 32	+ 69	+105	+129	+143	+126	+114	+ 99	+ 86
−236	−148	− 66	+ 3	+ 43	+ 64	+ 89	+119	+134	+126	+121	+ 94	+ 95
−160	−137	− 87	− 44	− 17	− 4	+ 28	+ 43	+ 52	+ 45	+ 39	+ 34	+ 35
−199	−147	− 83	− 26	+ 13	+ 33	+ 58	+ 81	+ 95	+ 87	+ 79	+ 65	+ 63
						at Kew.						
+ 12	+ 8	+ 4	− 9	− 14	− 13	− 18	− 11	− 11	− 17	− 12	− 9	− 9
+ 3	− 4	− 12	− 22	− 28	− 31	− 24	− 28	− 24	− 23	− 17	− 12	− 8
+ 7	− 3	− 14	− 18	− 19	− 18	− 11	− 13	− 20	− 19	− 11	− 13	− 4
+ 10	+ 5	− 3	− 12	− 13	− 20	− 14	− 12	− 12	− 14	− 8	− 2	− 3
+ 8	+ 2	− 7	− 15	− 19	− 20	− 17	− 16	− 17	− 18	− 12	− 9	− 6

TABLE V.—*Diurnal Inequalities at Greenwich and Kew on quiet days*
(As observed, no correction for non-cyclic

Hour	Midn.	1	2	3	4	5	6	7	8	9	10
					Declination.						
March—	′	′	′	′	′	′	′	′	′	′	′
Greenwich .	−1·3	−1·1	−0·7	−1·1	−1·6	−1·5	−1·8	−2·8	−4·4	−4·4	−2·1
Kew . .	−1·2	−1·0	−1·1	−1·0	−1·6	−1·5	−1·9	−2·8	−4·4	−4·5	−2·5
Excess of Kew	+0·1	+0·1	−0·4	+0·1	0·0	0·0	−0·1	0·0	0·0	0·1	−0·4
June—											
Greenwich .	−0·3	−0·4	−1·0	−1·3	−2·4	−3·5	−4·8	−5·1	−4·9	−3·9	−1·7
Kew . .	−0·3	−0·5	−0·9	−1·7	−2·3	−3·6	−4·9	−5·6	−5·0	−3·7	−1·6
Excess of Kew	0·0	−0·1	+0·1	−0·4	+0·1	−0·1	−0·1	−0·5	−0·1	+0·2	+0·1
September—											
Greenwich .	−1·6	−1·9	−1·6	−1·5	−1·4	−1·8	−2·5	−3·2	−3·1	−2·0	0·0
Kew . .	−2·3	−2·3	−2·3	−2·1	−2·5	−2·6	−3·2	−4·2	−4·1	−2·6	+0·1
Excess of Kew	−0·7	−0·4	−0·7	−0·6	−1·1	−0·8	−0·7	−1·0	−1·0	−0·6	+0·1
December—											
Greenwich .	−0·5	−0·6	−0.5	−0·6	−0·5	−0·7	−0·8	−0·9	−1·1	−1·3	−0·6
Kew . .	−0·7	−0·5	−0·5	−0·5	−0·5	−0·7	−0·9	−1·0	−1·1	−1·4	−0·4
Excess of Kew	−0·2	+0·1	0·0	+0·1	0·0	0·0	−0·1	−0·1	0·0	−0·1	+0·2
					Horizontal Force.						
March—											
Greenwich .	+ 6	+ 4	+ 3	+ 2	+ 2	+ 3	+ 3	+ 1	− 7	− 17	− 24
Kew . .	+ 6	+ 3	+ 3	+ 3	+ 3	+ 5	+ 6	+ 4	− 3	− 13	− 22
Excess of Kew	0	− 1	0	+ 1	+ 1	+ 2	+ 3	+ 3	+ 4	+ 4	+ 2
June—											
Greenwich .	+ 6	+ 7	+ 6	+ 7	+ 1	− 2	− 8	− 17	− 25	− 29	− 33
Kew . .	+ 5	+ 4	+ 5	+ 4	+ 3	+ 2	− 5	− 12	− 20	− 29	− 34
Excess of Kew	− 1	− 3	− 1	− 3	+ 2	+ 4	+ 3	+ 5	+ 5	0	− 1
September—											
Greenwich .	+ 11	+ 7	+ 5	+ 5	+ 6	+ 5	+ 1	− 6	− 18	− 28	− 28
Kew . .	+ 10	+ 7	+ 6	+ 5	+ 5	+ 5	0	− 6	− 18	− 27	− 29
Excess of Kew	− 1	0	+ 1	0	− 1	0	− 1	0	0	+ 1	− 1
December—											
Greenwich .	+ 2	+ 1	0	− 1	+ 1	+ 2	+ 2	+ 1	− 1	− 7	− 11
Kew . .	0	+ 1	− 1	− 1	+ 1	+ 2	+ 2	+ 1	− 1	− 4	− 10
Excess of Kew	− 2	0	− 1	0	0	0	0	0	0	+ 3	+ 1
					Vertical Force.						
March—											
Greenwich .	+ 1	− 1	− 1	− 3	− 3	− 1	+ 1	+ 6	+ 5	− 2	− 8
Kew . .	− 1	0	0	+ 1	+ 2	+ 3	+ 5	+ 7	+ 5	0	− 8
Excess of Kew	− 2	+ 1	+ 1	+ 4	+ 5	+ 4	+ 4	+ 1	0	+ 2	0
June—											
Greenwich .	− 1	− 2	− 2	− 2	− 2	0	+ 3	+ 5	+ 2	− 1	− 7
Kew . .	0	− 2	− 3	− 2	− 1	+ 1	+ 4	+ 5	+ 1	0	− 7
Excess of Kew	+ 1	0	− 1	0	+ 1	+ 1	+ 1	0	− 1	+ 1	0
September—											
Greenwich .	+ 2	0	+ 1	+ 1	+ 2	+ 1	+ 2	+ 4	+ 2	− 2	− 10
Kew . .	− 6	− 5	− 4	− 3	− 2	− 2	0	+ 2	0	− 4	− 10
Excess of Kew	− 8	− 5	− 5	− 4	− 4	− 3	− 2	− 2	− 2	− 2	0
December—											
Greenwich .	+ 2	+ 1	+ 2	0	+ 1	0	0	0	0	+ 1	0
Kew . .	− 1	− 1	− 1	− 1	− 1	− 2	− 2	− 2	− 1	− 2	− 2
Excess of Kew	− 3	− 2	− 3	− 1	− 2	− 2	− 2	− 2	− 1	− 3	− 2

In this Table the Values of Horizontal and *compared, for the Equinoctial and Solstitial Months of the Year* 1894.

increment being here applied.)

11	Noon	13	14	15	16	17	18	19	20	21	22	23
						Declination.						
′	′	′	′	′	′	′	′	′	′	′	′	′
+1·5	+4·0	+5·9	+5·5	+3.8	+2·0	+0·9	+0·5	+0·3	−0·2	−0·4	−0·7	−0·9
+1·1	+4·6	+6·1	+5·9	+4·2	+2·1	+0·9	+0·5	+0·4	0·0	−0·2	−0·4	−0·8
−0·4	+0·6	+0·2	+0·4	+0·4	+0·1	0·0	0·0	+0·1	+0·2	+0·2	+0·3	+0·1
+1·0	+3·8	+5·2	+4·9	+4·2	+3·7	+2·1	+1·5	+0·8	+0·7	+0·9	+0·8	−1·0
+1·1	+4·1	+5·9	+5·0	+4·3	+3·6	+2·0	+1·4	+0·9	+0·6	+0·6	+0·6	−1·0
+0·1	+0·3	+0·7	+0·1	+0·1	−0·1	−0·1	−0·1	+0·1	−0·1	−0·3	−0·2	0·0
+2·8	+4·9	+5·7	+4·8	+3·3	+2·1	+0·8	+0·4	−0·3	−0·5	−0·6	−0·8	−1·2
+3·6	+5·9	+7·4	+6·0	+3·7	+2·1	+0·7	+0·3	0·0	−0·4	−0·3	−0·4	−0·9
+0·8	+1·0	+1·7	+1·2	+0·4	0·0	−0·1	−0·1	+0·3	+0·1	+0·3	+0·4	+0·3
+0·7	+1·3	+2·2	+2·6	+2·1	+1·2	+0·8	+0·4	0·0	−0·1	−0·4	−1·1	−1·2
+0·7	+1·7	+2·6	+2·6	+2·2	+1·2	+0·5	+0·2	−0·1	−0·5	−0·7	−1·0	−1·0
0·0	+0·4	+0·4	0·0	+0·1	0·0	−0·3	−0·2	−0·1	−0·4	−0·3	+0·1	+0·2
						Horizontal Force.						
−25	−19	−9	0	+5	+7	+8	+9	+10	+11	+10	+8	+10
−24	−18	−9	−3	+2	+6	+4	+7	+7	+8	+7	+7	+9
+1	+1	0	−3	−3	−1	−4	−2	−3	−3	−3	−1	−1
−33	−25	−20	−9	+11	+20	+20	+23	+27	+23	+18	+18	+14
−30	−21	−11	−3	+7	+16	+18	+22	+22	+18	+16	+14	+9
+3	+4	+9	+6	−4	−4	−2	−1	−5	−5	−2	−4	−5
−25	−14	−3	0	+2	+3	+6	+9	+11	+15	+14	+11	+9
−24	−16	−5	−4	−2	0	+4	+10	+13	+15	+15	+15	+14
+1	−2	−2	−4	−4	−3	−2	+1	+2	0	+1	+4	+5
−13	−12	−6	−1	+1	+5	+9	+8	+7	+7	+3	0	+1
−10	−10	−6	−3	−2	+2	+5	+7	+6	+6	+2	+1	+2
+3	+2	0	−2	−3	−3	−4	−1	−1	−1	−1	+1	+1
						Vertical Force.						
−13	−15	−11	−2	+5	+7	+6	+6	+4	+6	+6	+5	+2
−13	−14	−8	−3	+3	+6	+5	+3	+2	+1	0	0	0
0	+1	+3	−1	−2	−1	−1	−3	−2	−5	−6	−5	−2
−14	−13	−11	−6	0	+6	+7	+11	+11	+8	+5	+3	−1
−12	−11	−8	−3	+1	+7	+9	+9	+9	+7	+4	+2	+1
+2	+2	+3	+3	+1	+1	+2	−2	−2	−1	−1	−1	+2
−17	−15	−10	−4	+3	+5	+5	+5	+6	+8	+6	+3	+3
−15	−11	−6	−2	+3	+7	+8	+7	+7	+7	+7	+7	+7
+2	+4	+4	+2	0	+2	+3	+2	+1	−1	+1	+4	+4
+3	+3	+3	+3	+3	+3	0	−3	−4	−5	−5	−4	−6
−1	−1	0	+2	+3	+4	+2	+1	0	+1	+1	+1	+2
−4	−4	−3	−1	0	+1	+2	+4	+4	+6	+6	+5	+8

Vertical Force are in c.g.s. measure × 10^5.

TABLE VI.—*Diurnal Inequalities and Diurnal Range at*

Month or Quarter	Declination									
	Sums of Hourly Values of Diurnal Inequality (corrected for Non-cyclic Increment)			Diurnal Range						
				Greenwich			Kew			
	Greenwich	Kew	K − G	As Observed *a*	Corrected for Noncyclic Increment *b*	*a* − *b*	As Observed *a*	Corrected for Noncyclic Increment *b*	*a* − *b*	K − G as made Cyclic
	′	′	′	′	′	′	′	′	′	′
January . .	28·24	29·52	+1·28	4·98	4·78	+0·20	5·22	4·99	+0·23	+0·21
February . .	34·56	35·95	+1·39	5·54	5·41	+0·13	5·72	5·64	+0·08	+0·23
March . . .	45·60	47·58	+1·98	9·44	9·36	+0·08	9·78	9·73	+0·05	+0·37
April . . .	48·68	51·45	+2·77	10·78	10·76	+0·02	11·30	11·26	+0·04	+0·50
May . . .	58·02	59·32	+1·30	11·70	11·62	+0·08	12·00	11·93	+0·07	+0·31
June . . .	58·02	59·26	+1·24	10·76	10·76	0·00	11·18	11·25	−0·07	+0·49
July . . .	58·20	57·46	−0·74	11·30	11·36	−0·06	11·18	11·29	−0·11	−0·07
August . . .	57·12	60·14	+3·02	11·38	11·48	−0·10	12·16	12·23	−0·07	+0·75
September . .	50·18	55·04	+4·86	9·50	9·56	−0·06	10·50	10·47	+0·03	+0·91
October . . .	43·68	45·48	+1·80	7·94	7·94	0·00	8·54	8·52	+0·02	+0·58
November . .	30·92	32·59	+1·67	5·60	5·58	+0·02	5·92	5·88	+0·04	+0·30
December . .	22·82	24·03	+1·21	3·98	3·80	+0·18	4·02	3·97	+0·05	+0·17
First Quarter .	36·13	37·68	+1·55	6·65	6·52	+0·13	6·91	6·79	+0·12	+0·27
Second Quarter .	54·91	56·68	+1·77	11·08	11·05	+0·03	11·49	11·48	+0·01	+0·43
Third Quarter .	55·17	57·55	+2·38	10·73	10·80	−0·07	11·28	11·33	−0·05	+0·53
Fourth Quarter .	32·47	34·03	+1·56	5·84	5·77	+0·07	6·16	6·12	+0·04	+0·35
Mean . . .	44·67	6·49	+1·82	8·57	8·53	+0·04	8·96	8·93	+0·03	+0·40

Greenwich and Kew on Quiet Days, 1890–1894, *compared.*

Horizontal Force										Month or Quarter
Sums of Hourly Values of Diurnal Inequality (corrected for Non-cyclic Increment)			Diurnal Range							
			Greenwich			Kew				
Greenwich	Kew	K−G	As Observed a	Corrected for Non-cyclic Increment b	$a-b$	As Observed a	Corrected for Non-cyclic Increment b	$a-b$	K−G as made Cyclic	
928	823	−105	197	187	+10	172	180	−8	−7	January
1250	1132	−118	250	230	+20	214	205	+9	−25	February
1788	1689	−99	307	298	+9	290	282	+8	−16	March
2460	2371	−89	418	405	+13	386	381	+5	−24	April
2792	2571	−221	466	449	+17	428	411	+17	−38	May
2980	2610	−370	488	477	+11	434	429	+5	−48	June
2906	2686	−220	471	465	+6	444	436	+8	−29	July
2952	2632	−320	491	476	+15	450	433	+17	−43	August
2246	2113	−133	395	381	+14	386	372	+14	−9	September
1960	1964	+4	349	319	+30	332	317	+15	−2	October
1546	1468	−78	264	253	+11	234	245	−11	−8	November
740	664	−76	146	141	+5	140	142	−2	+1	December
1322	1215	−107	251	238	+13	225	222	+3	−16	First Quarter
2744	2517	−227	457	444	+13	416	407	+9	−37	Second Quarter
2701	2477	−224	452	441	+11	427	414	+13	−27	Third Quarter
1415	1365	−50	253	238	+15	235	234	+1	−4	Fourth Quarter
2045	1893	−2	353	340	+13	326	319	+7	−21	Mean

TABLE VII.—*Non-cyclic Increment at Greenwich and Kew on Quiet Days, 1890–1895, compared.*

Month or Quarter	Declination								Horizontal Force								Vertical Force							
	Non-cyclic Increment		Number of Individual Months						Non-cyclic Increment		Number of Individual Months						Non-cyclic Increment		Number of Individual Months					
	Greenwich	Kew	Greenwich			Kew			Greenwich	Kew	Greenwich			Kew			Greenwich	Kew	Greenwich			Kew		
	′	′	+	*o*	−	+	*o*	−			+	*o*	−	+	*o*	−			+	*o*	−	+	*o*	−
January .	+0·47	+0·63	4	0	2	6	0	0	+53	+50	6	0	0	5	0	1	− 4	−52	3	0	3	0	0	6
February .	+0·45	+0·33	4	0	2	4	0	2	+63	+57	5	0	1	5	1	0	−44	+ 5	0	0	6	3	0	3
March .	+0·27	+0·18	3	3	0	3	0	3	+34	+28	5	0	1	5	1	0	−45	+13	1	0	5	2	2	2
April .	+0·17	+0·12	4	1	1	3	1	2	+45	+20	5	0	1	4	1	1	− 4	−22	2	0	4	2	0	4
May . .	+0·13	+0·07	3	0	3	3	0	3	+39	+38	5	0	1	5	1	0	− 4	−12	2	2	2	3	0	3
June. .	+0·05	−0·17	4	0	2	3	0	3	+27	+22	5	0	1	4	1	1	−20	−28	1	1	4	1	0	5
July . .	−0·15	−0·23	2	1	3	3	0	3	+31	+27	4	0	2	4	2	0	+ 6	−13	3	0	3	1	0	5
August .	−0·35	−0·30	1	1	4	1	1	4	+34	+37	6	0	0	5	0	1	− 9	− 8	1	2	3	3	0	3
September	−0·33	+0·12	2	0	4	3	0	3	+38	+38	5	0	1	6	0	0	−14	+30	2	2	2	3	1	2
October .	−0·20	+0·03	1	0	5	2	1	3	+69	+50	6	0	0	6	0	0	−12	+ 5	2	1	3	3	0	3
November	+0·13	+0·18	3	1	2	3	1	2	+60	+53	5	0	1	6	0	0	−44	−12	0	1	5	2	0	3
December.	−0·27	−0·10	1	0	5	1	2	3	+23	+15	5	0	1	5	0	1	−34	− 6	1	0	5	2	0	3
1st Quarter	+0·40	+0·38		—			—		+50	+45		—			—		−31	−11		—			—	
2nd Quarter	+0·12	+0·01		—			—		+37	+27		—			—		− 9	−21		—			—	
3rd Quarter	−0·28	−0·14		—			—		+34	+34		—			—		− 6	+ 3		—			—	
4th Quarter	−0·11	+0·04		—			—		+51	+39		—			—		−30	− 4		—			—	
Mean .	+0·03	+0·07		—			—		+43	+36		—			—		−19	− 8		—			—	
Totals of Months .	—	—	32	7	33	35	6	31	—	—	62	0	10	60	7	5	—	—	18	9	45	25	3	42*

* The vertical force magnetograph at Kew was out of action in November and December 1890, reducing the months from seventy-two to seventy.

TABLE IX.—*Non-cyclic Increment at Greenwich and Kew on Quiet Days, for Years, compared.*

Year	Declination		Horizontal Force		Vertical Force	
	Greenwich	Kew	Greenwich	Kew	Greenwich	Kew
	′	′				
1890	− 0·23	− 0·36	+19	+23	−12	+15*
1891	+ 0·08	+ 0·29	+37	+23	− 8	−12
1892	− 0·20	+ 0·14	+67	+53	−39	−20
1893	+ 0·15	+ 0·26	+44	+40	−24	−26
1894	+ 0·24	+ 0·15	+33	+33	− 4	+12
1895	+ 0·15	− 0·05	+57	+44	−27	−15
Mean . .	+ 0·03	+ 0·07	+43	+36	−19	− 8

* This value depends on ten months only. See note to Table VII.

TABLE VIII.—*Non-cyclic Increment at Greenwich on Quiet Days, 1889—1896.*

Month, Quarter, or Year	Declination							Horizontal Force							Vertical Force						
	Non-cyclic Increment				Individual Months			Non-cyclic Increment				Individual Months			Non-cyclic Increment				Individual Months		
	Greatest Monthly Value	Least Monthly Value	Difference	Mean				Greatest Monthly Value	Least Monthly Value	Difference	Mean				Greatest Monthly Value	Least Monthly Value	Difference	Mean			
	′	′	′	′	+	*o*	−					+	*o*	−					+	*o*	−
January	+1·9	−2·6	4·5	+0·05	5	0	3	+113	−91	204	+30	7	0	1	+52	−74	126	− 1	4	0	4
February	+2·4	−0·6	3·0	+0·25	4	0	4	+108	−16	124	+58	7	0	1	−17	−83	66	−48	0	0	8
March	+1·1	0·0	1·1	+0·25	4	4	0	+137	−57	194	+42	7	0	1	+22	−83	105	−36	1	1	6
April	+0·6	−0·5	1·1	+0·14	5	1	2	+137	− 5	142	+52	7	0	1	+52	−35	87	+ 8	4	0	4
May	+0·9	−0·3	1·2	+0·13	4	1	3	+ 91	−53	144	+48	7	0	1	+31	−52	83	− 3	3	2	3
June	+0·7	−1·0	1·7	+0·04	5	0	3	+ 64	− 9	73	+35	7	0	1	+17	−44	61	−14	3	1	4
July	+0·4	−1·0	1·4	−0·15	2	2	4	+104	−11	115	+34	6	0	2	+35	−35	70	0	3	1	4
August	+0·8	−0·7	1·5	−0·23	2	1	5	+ 93	+ 5	88	+32	8	0	0	+44	−74	118	− 7	2	2	4
September	+0·1	−1·0	1·1	−0·31	2	0	6	+ 68	−18	86	+32	6	0	2	+22	−61	83	−18	2	2	4
October	+0·9	−0·7	1·6	−0·24	1	0	7	+117	−15	132	+56	7	0	1	+44	−83	127	−18	2	2	4
November	+1·1	−1·4	2·5	+0·06	3	1	4	+ 84	−22	106	+41	5	0	3	0	−87	87	−43	0	1	7
December	+0·3	−0·7	1·0	−0·28	1	0	7	+ 51	−48	99	+11	5	1	2	+26	−87	113	−22	2	1	5
1st Quarter	—	—	2·9	+0·18	—			—	—	174	+43	—			—	—	99	−28	—		
2nd Quarter	—	—	1·3	+0·10	—			—	—	120	+45	—			—	—	77	− 3	—		
3rd Quarter	—	—	1·3	−0·23	—			—	—	96	+33	—			—	—	90	− 8	—		
4th Quarter	—	—	1·7	−0·15	—			—	—	112	+36	—			—	—	109	−28	—		
Mean	—	—	1·8	−0·02	—			—	—	126	+39	—			—	—	94	−17	—		
1889	+0·8	−0·5	1·3	−0·11	3	1	8	+ 62	−48	110	+19	9	0	3	+35	−44	79	− 8	4	2	6
1890	+0·2	−0·7	0·9	−0·23	3	2	7	+ 84	−57	141	+19	8	0	4	+52	−87	139	−12	5	1	6
1891	+0·9	−1·4	2·3	+0·08	7	1	4	+ 77	−16	93	+37	11	0	1	+44	−83	127	− 8	4	2	6
1892	+1·1	−1·0	2·1	−0·20	3	1	8	+137	+ 5	132	+67	12	0	0	0	−74	74	−39	0	1	11
1893	+1·9	−0·6	2·5	+0·15	5	1	6	+113	− 5	118	+44	11	0	1	+35	−74	109	−24	1	2	9
1894	+2·4	−1·0	3·4	+0·24	7	0	5	+117	−53	170	+33	8	0	4	+44	−87	131	− 4	5	2	5
1895	+0·7	−0·4	1·1	+0·15	7	2	3	+108	+ 9	99	+57	12	0	0	+35	−83	118	−27	3	1	8
1896	+0·6	−2·6	3·2	−0·27	3	2	7	+137	−91	228	+38	8	1	3	+52	−70	122	−11	4	2	6
Mean	—	—	2·1	—	—			—	—	136	—	—			—	—	112	—	—		
Totals of Months	—	—	—	—	38	10	48	—	—	—	—	79	1	16	—	—	—	—	26	13	57

TABLE X.—*Non-cyclic Increment at Greenwich on Quiet*

Month, Quarter, or Year	Declination				
	Preceding Noon to Noon p	Midnight to Midnight m	Noon to following Noon f	$\frac{1}{2}(p+f)=n$	$m-n$
	′	′	′	′	′
January	−0·04	+0·05	+0·16	+0·06	−0·01
February . . .	+0·05	+0·25	+0·40	+0·22	+0·03
March	−0·35	+0·25	+0·47	+0·06	+0·19
April	−0·81	+0·14	+0·60	−0·11	+0·25
May	+0·19	+0·13	+0·25	+0·22	−0·09
June	−0·28	+0·04	+0·11	−0·08	+0·12
July	−0·31	−0·15	+0·44	+0·06	−0·21
August	−0·21	−0·23	−0·04	−0·13	−0·10
September . . .	−0·12	−0·31	+0·11	−0·01	−0·30
October . . .	−0·79	−0·24	+0·31	−0·24	0·00
November . . .	−0·12	+0·06	+0·21	+0·04	+0·02
December . . .	−0·31	−0·28	+0·63	+0·16	−0·44
First Quarter . .	−0·11	+0·18	+0·34	+0·11	+0·07
Second Quarter . .	−0·30	+0·10	+0·32	+0·01	+0·09
Third Quarter . .	−0·21	−0·23	+0·17	−0·02	−0·21
Fourth Quarter . .	−0·41	−0·15	+0·38	−0·02	−0·13
Mean	−0·26	−0·02	+0·30	+0·02	+0·04
1889	−0·22	−0·11	+0·06	−0·08	−0·03
1890	−0·09	−0·23	−0·02	−0·06	−0·17
1891	−0·18	+0·08	+0·49	+0·15	−0·07
1892 . . .	+0·01	−0·20	+0·45	+0·23	−0·43
1893	−0·12	+0·15	+0·36	+0·12	+0·03
1894	−0·53	+0·24	+0·24	−0·15	+0·39
1895	−0·48	+0·15	+0·16	−0·16	+0·31
1896	−0·47	−0·27	+0·70	+0·12	−0·39

Days, as variously determined, compared, 1889-1896.

Horizontal Force					Vertical Force				
Preceding Noon to Noon p	Midnight to Midnight m	Noon to following Noon f	$\frac{1}{2}(p+f)=n$	$m-n$	Preceding Noon to Noon p	Midnight to Midnight m	Noon to following Noon f	$\frac{1}{2}(p+f)=n$	$m-n$
+32	+30	+ 8	+20	+10	− 4	− 1	−17	−11	+10
+ 4	+58	+50	+27	+31	−15	−48	−49	−32	−16
+45	+42	+ 6	+26	+16	−45	−36	−28	−37	+ 1
+21	+52	+55	+38	+14	−27	+ 8	−22	−25	+33
+61	+48	0	+30	+18	−27	− 3	+16	− 6	+ 3
+29	+35	+30	+30	+ 5	−12	−14	−33	−23	+ 9
− 9	+34	+47	+19	+15	−20	0	−19	−19	+19
−20	+32	+47	+13	+19	−10	− 7	−18	−14	+ 7
+13	+32	− 4	+ 4	+28	−46	−18	−19	−32	+14
+42	+56	+28	+35	+21	−34	−18	+ 9	−12	− 6
+20	+41	+22	+21	+20	−38	−43	−31	−34	− 9
+44	+11	−12	+16	− 5	−20	−22	− 3	−11	−11
+27	+43	+21	+24	+19	−21	−28	−31	−26	− 2
+37	+45	+28	+32	+13	−22	− 3	−13	−17	+14
− 5	+33	+30	+12	+21	−25	− 8	−19	−22	+14
+35	+36	+13	+24	+12	−31	−28	− 8	−20	− 8
+23	+39	+23	+23	+16	−25	−17	−18	−21	+ 4
+12	+19	+14	+13	+ 6	−25	− 8	− 4	−14	+ 6
+17	+19	+ 5	+11	+ 8	−19	−12	− 7	−13	+ 1
+ 1	+37	+65	+33	+ 4	− 2	− 8	−20	−11	+ 3
+44	+67	+26	+35	+32	−47	−39	−19	−33	− 6
+19	+44	+27	+23	+21	−53	−24	− 7	−30	+ 6
+23	+33	+21	+22	+11	+ 8	− 4	−39	−15	+11
+29	+57	+18	+24	+33	−26	−27	−23	−24	− 3
+43	+38	+ 8	+25	+13	−34	−11	−24	−29	+18

TABLE XI.—*Diurnal Range at Greenwich as*

Month, Quarter, or Year	Declination								Horizon-		
	Quiet Days				*b*—*c*				Quiet Days		
	As Observed *a*	Corrected for Non-cyclic Increment *b*	*a*—*b*	All Days *c*	Greatest Monthly Value	Least Monthly Value	Difference	Mean	As Observed *a*	Corrected for Non-cyclic Increment *b*	*a*—*b*
	′	′	′	′	′	′	′	′			
January .	5·04	4·81	+0·23	5.58	+0·7	—3·3	4·0	—0·77	188	179	+ 9
February .	6·06	5·85	+0·21	7·11	—0·2	—3·2	3·0	—1·26	257	232	+25
March . .	9·03	8·96	+0·07	9·14	+0·5	—0·8	1·3	—0·18	319	299	+20
April . .	10·80	10·78	+0·02	11·15	+1·1	—1·3	2·4	—0·37	442	423	+19
May . .	11·00	10·97	+0·03	10·72	+1·7	—1·5	3·2	+0·25	454	435	+19
June . .	10·88	10·86	+0·02	10·85	+1·7	—1·3	3·0	+0·01	479	464	+15
July . .	10·79	10·84	—0·05	10·95	+0·5	—0·8	1·3	—0·11	456	444	+12
August . .	10·77	10·84	—0·07	10·69	+1·8	—0·8	2·6	+0·15	471	457	+14
September .	9·54	9·59	—0·05	9·40	+1·8	—1·2	3·0	+0·19	413	397	+16
October . .	7·47	7·49	—0·02	8·06	0·0	—1·5	1·5	—0·57	353	329	+24
November .	5·21	5·12	+0·09	6·28	—0·1	—2·8	2·7	—1·16	251	241	+10
December .	4·09	4·01	+0·08	5·19	—0·3	—1·9	1·6	—1·18	147	147	0
1st Quarter .	6·71	6·54	+0·17	7·28	—	—	2·8	—0·74	255	237	+18
2nd Quarter .	10·89	10·87	+0·02	10·91	—	—	2·9	—0·04	458	441	+17
3rd Quarter .	10·37	10·42	—0·05	10·35	—	—	2·3	+0·07	447	433	+14
4th Quarter .	5·59	5·54	+0·05	6·51	—	—	1·9	—0·97	250	239	+11
Mean . .	8·39	8·34	+0·05	8·76	—	—	2·5	—0·42	352	337	+15
1889 . .	6·45	6·48	—0·03	6·67	+1·1	—0·7	1·8	—0·19	261	252	+ 9
1890 . .	6·78	6·81	—0·03	7·20	+0·5	—1·3	1·8	—0·39	263	256	+ 7
1891 . .	8·18	8·08	+0·10	8·46	+0·7	—1·4	2·1	—0·38	350	338	+12
1892 . .	9·75	9·78	—0·03	9·62	+1·7	—1·2	2·9	+0·16	398	370	+28
1893 . .	10·13	10·06	+0·07	10·40	+1·3	—1·5	2·8	—0·34	428	414	+14
1894 . .	9·02	8·89	+0·13	9·45	+0·5	—1·7	2·2	—0·56	414	403	+11
1895 . .	8·78	8·75	+0·03	9·64	+1·8	—3·3	5·1	—0·89	380	360	+20
1896 . .	8·01	7·90	+0·11	8·64	+1·8	—3·2	5·0	—0·74	326	306	+20
Mean . .	—	—	—	—	—	—	3·0	—	—	—	—

variously determined, compared, 1889–1896.

tal Force					Vertical Force							
	$b-c$				Quiet Days				$b-c$			
All Days c	Greatest Monthly Value	Least Monthly Value	Difference	Mean	As Observed a	Corrected for Non-cyclic Increment b	$a-b$	All Days c	Greatest Monthly Value	Least Monthly Value	Difference	Mean
163	+ 73	− 31	104	+16	114	100	+14	109	+22	− 44	66	− 9
200	+ 95	− 5	100	+32	125	131	− 6	175	+22	−127	149	−44
313	+ 59	− 53	112	−14	216	221	− 5	257	+13	−109	122	−36
447	+ 33	− 88	121	−24	245	243	+ 2	298	−13	−162	149	−55
449	+ 64	−117	181	−14	312	309	+ 3	356	+17	−105	122	−47
496	+ 68	−108	176	−32	257	253	+ 4	303	+26	−118	144	−50
496	− 4	−123	119	−52	253	252	+ 1	277	+44	− 79	123	−25
470	+ 64	− 82	146	−13	212	210	+ 2	233	+26	− 70	96	−23
393	+ 64	− 51	115	+ 4	195	194	+ 1	217	+26	−101	127	−23
338	+ 38	− 91	129	− 9	157	157	0	196	+17	− 61	78	−39
212	+101	− 26	127	+29	115	114	+ 1	157	+ 4	−101	105	−43
150	+ 16	− 37	53	− 3	105	96	+ 9	105	+35	− 44	79	− 9
225	—	—	105	+12	152	151	+ 1	180	—	—	112	−29
464	—	—	159	−23	271	268	+ 3	319	—	—	138	−51
453	—	—	127	−20	220	219	+ 1	242	—	—	115	−23
233	—	—	103	+ 6	126	122	+ 4	153	—	—	87	−31
344	—	—	124	− 7	192	190	+ 2	224	—	—	113	−34
248	+ 66	− 42	108	+ 4	163	163	0	168	+35	− 52	87	− 5
253	+ 44	− 46	90	+ 3	176	170	+ 6	173	+44	− 66	110	− 3
323	+ 73	− 55	128	+15	192	189	+ 3	222	+22	−101	123	−33
402	+ 64	−123	187	−32	228	231	− 3	257	+31	− 79	110	−26
413	+ 90	−108	198	+ 1	202	199	+ 3	233	+17	−118	135	−34
411	+101	− 77	178	− 8	197	192	+ 5	248	+17	−162	179	−56
370	+ 95	− 66	161	−10	191	187	+ 4	242	+26	−127	153	−55
331	+ 38	−117	155	−25	190	190	0	245	− 9	−109	100	−55
—	—	—	151	—	—	—	—	—	—	—	125	—

TABLE XII.—*Excess of Absolute Values of Magnetic Elements on Quiet Days at Greenwich above the Values of the All Day Tabulation,* 1889–1896.

Month, Quarter, or Year	Declination					Horizontal Force					Vertical Force				
	Greatest Monthly Excess	Least Monthly Excess	Difference	Mean Excess	Individual Months	Greatest Monthly Excess	Least Monthly Excess	Difference	Mean Excess	Individual Months	Greatest Monthly Excess	Least Monthly Excess	Difference	Mean Excess	Individual Months
	′	′	′	′	+ o −					+ o −					+ o
January .	+0·5	−0·2	0·7	+0·09	5 0 3	+132	− 9	141	+ 42	5 0 3	+109	−105	214	+ 5	4 1
February .	+0·4	−0·2	0·6	+0·20	6 1 1	+106	−42	148	+ 41	6 0 2	+ 9	− 87	96	− 22	2 1
March .	+0·6	−0·1	0·7	+0·20	5 2 1	+ 75	−20	95	+ 34	6 0 2	+ 66	− 44	110	− 15	1 0
April . .	+0·2	−0·4	0·6	−0·03	3 2 3	+ 75	−24	99	+ 42	7 0 1	+ 39	− 96	135	− 16	3 1
May . .	+0·5	−0·4	0·9	+0·10	5 0 3	+ 57	−15	72	+ 16	5 0 3	+ 4	− 48	52	− 20	1 0
June . .	+0·3	−0·2	0·5	+0·05	3 3 2	+ 48	−26	74	+ 12	5 0 3	+ 35	− 57	92	− 6	3 1
July . .	+0·3	−0·3	0·6	−0·03	3 2 3	+ 42	− 4	46	+ 15	5 1 2	+ 31	− 66	97	− 16	3 0
August .	+0·2	−0·2	0·4	+0·06	5 1 2	+ 31	−27	58	+ 4	4 0 4	+ 26	− 48	74	− 4	4 0
September .	+0·4	−0·4	0·8	+0·06	5 0 3	+104	−26	130	+ 31	5 0 3	+ 79	− 48	127	+ 7	5 0
October .	+0·4	−0·5	0·9	+0·01	4 0 4	+106	− 4	110	+ 49	7 0 1	+ 87	−118	205	− 22	3 0
November .	+0·6	−0·1	0·7	+0·24	6 0 2	+ 99	− 4	103	+ 49	7 0 1	+ 61	− 44	105	+ 3	3 0
December .	+0·3	−0·2	0·5	−0·02	2 1 5	+ 97	+ 2	95	+ 57	8 0 0	+ 39	− 57	96	− 7	3 0
1st Quarter	—	—	0·7	+0·16	—	—	—	128	+ 39	—	—	—	140	− 11	—
2nd Quarter	—	—	0·7	+0·04	—	—	—	82	+ 23	—	—	—	93	− 14	—
3rd Quarter	—	—	0·6	+0·03	—	—	—	78	+ 17	—	—	—	99	− 4	—
4th Quarter	—	—	0·7	+0·08	—	—	—	103	+ 52	—	—	—	135	− 9	—
Mean .	—	—	0·7	+0·08	—	—	—	98	+ 33	—	—	—	117	− 9	—
1889 . .	+0·6	−0·2	0·8	+0·12	7 2 3	+ 84	−42	126	+ 21	8 1 3	+ 52	− 39	91	− 4	3 1
1890 . .	+0·5	−0·4	0·9	+0·01	5 2 5	+ 46	−13	59	+ 11	7 0 5	+ 66	−118	184	− 8	5 2
1891 . .	+0·1	−0·4	0·5	−0·12	3 1 8	+104	− 9	113	+ 38	10 0 2	+109	− 66	175	− 7	3 1
1892 . .	+0·6	−0·3	0·9	+0·07	5 1 6	+ 75	−33	108	+ 32	9 0 3	+ 26	−114	140	− 26	4 0
1893 . .	+0·4	−0·5	0·9	+0·19	10 0 2	+106	−20	126	+ 36	8 0 4	+ 39	− 87	126	− 14	5 0
1894 . .	+0·4	−0·3	0·7	+0·12	9 2 1	+115	−24	139	+ 53	11 0 1	+ 79	− 31	110	+ 14	7 0
1895 . .	+0·5	−0·2	0·7	+0·11	6 3 3	+106	−26	132	+ 34	9 0 3	+ 87	−105	192	− 1	6 0
1896 . .	+0·5	−0·2	0·7	+0·12	7 1 4	+132	−13	145	+ 37	8 0 4	+ 26	− 57	83	− 28	2 0
Mean .	—	—	0·8	—	—	—	—	118	—	—	—	—	138	—	—
Totals of Months .	—	—	—	—	52 12 32	—	—	—	—	70 1 25	—	—	—	—	35 4

An Account of the late Professor JOHN COUCH ADAMS'S *Determination of the Gaussian Magnetic Constants.* *By* Professor W. GRYLLS ADAMS.

I propose to give the Conference a short account of the work done by my brother on the theory of terrestrial magnetism, and to give his determination of the Gaussian magnetic constants. This work was first taken up by the late Professor John Couch Adams just fifty years ago, not long after the discovery of the planet Neptune. I find from his papers, which he delivered to me before his death, and which he asked me to examine to see if they could be brought into form for publication, that the earliest work which he did on this subject was begun in the year 1849, and that he was led to it by the study of the translation of Gauss's Memoir on the Theory of Terrestrial Magnetism given in Taylor's 'Scientific Memoirs' which was published in 1841. Gauss himself says in that memoir that he was stimulated to undertake the work on the publication of Sabine's map of the total intensity in the seventh Report of the British Association (*i.e.* in 1837), but that the data are very scanty for the accurate determination of the magnetic constants. For their accurate determination data should be supplied from accurate observations of magnetic declination, horizontal intensity, and dip, taken at stations uniformly distributed, as in a network, over the surface of the Earth.

Not only fifty years ago, when Gauss wrote, but even to the present day, the progress made in the theory of terrestrial magnetism has suffered from the lack of data derived from observations, because even now there are few magnetic Observatories in existence, and those few are for the most part grouped very close together, leaving other parts of the Earth, and especially the southern hemisphere, almost entirely wanting in the facts of observation without which all theories can be but visionary.

In his calculations on the magnetic potential of the Earth and on the theoretical expression of the magnetic components X, Y and Z, to the north, to the west, and vertically downwards respectively, Gauss expressed them for any point of the Earth's surface in series consisting of quantities to which he gave the name of magnetic constants, with coefficients involving Legendre's coefficients, and which are functions of the colatitude of the point.

From the very imperfect data which he possessed, Gauss determined the numerical values of the magnetic constants by his equations up to terms of the fourth order—*i.e.* he determined the values of the first twenty-four magnetic constants, three of the first order, five of the second, seven of the third, and nine of the fourth order.

No one could be more conscious of the fact than Gauss himself was that his data were so meagre and so insufficient that he could by no means rely on the values derived from them, and I fear that even now, at the end of the nineteenth century, we must say with him that the observed facts are far too scanty and that our stock of observations is still too small to enable us to get out trustworthy values of the magnetic potential and the magnetic elements for a given epoch. For this purpose the observations should be strictly contemporaneous, and we require more Observatories where continuous records are taken.

For Gauss's method, which was also the method followed in practice by my brother, it is important for the accuracy and trustworthiness of the resulting values of the magnetic constants that the observations shall be taken from stations distributed as uniformly as possible over the Earth's surface; whereas we see that in the northern hemisphere the Observatories which exist are very unequally distributed, and that in the southern hemisphere there are only three first-class magnetic Observatories where continuous records are taken, viz. those of Batavia, Mauritius, and Melbourne.

For the more ready development of the theory of terrestrial magnetism, Professor J. C. Adams established simple and convenient relations between successive Legendre's coefficients and their derived differential coefficients regarded as functions of the colatitude $\theta = \cos^{-1}\mu$.

Taking P_n to represent Legendre's n^{th} coefficient, he employed the notation Q_n^m to denote the value of

$$\frac{d^m P_n}{d\mu^m} (1-\mu^2)^{\frac{m}{2}}$$

and found certain simple and useful relations between successive values of Q for different values of n and m.

He also employed the symbol G_n^m to represent the Gaussian function

$$\mu^{n-m} - \frac{(n-m)(n-m-1)}{2(2n-1)} \mu^{n-m-2} + \text{\&c.},$$

and found it convenient to employ the symbol H_n^m as $= G_n^m (1-\mu^2)^{\frac{m}{2}}$.

He worked out very simple relations between successive values of G for different values of n and m, and proceeded to determine the numerical values of these functions (1) for every degree of latitude on a sphere, and (2) for every degree of the geographical colatitude on a spheroid of eccentricity equal to that of the Earth itself. He also obtained very simple relations between successive values of H and its differential coefficients for different values of n and m, and expressed the magnetic potential V and the magnetic forces X, Y and Z in terms of these symbols H_n^m. He also determined the values of these functions H_n^m for belts of latitude 5° apart (1) on a sphere, and (2) on a spheroid whose eccentricity equals that of the Earth's surface. Two distinct schemes of calculation were employed to determine the numerical values of G_n^m and also of H_n^m for different values of n and m, including all values of n and m from 0 to 10, and these calculations were made by different people and the results of the calculations compared to ensure the accuracy of the results.

In the case of the spheroid, the functions G_n^m and H_n^m are regarded as functions of the *geographical* colatitude θ, and $\mu = \cos\theta$, and the symbols G'^m_n and H'^m_n are the same functions of the *geocentric* colatitude θ' of the same point, where $\mu' = \cos\theta'$.

A new theorem giving the values of $G'-G'$ for different values of n and m is established, by means of which the accuracy of the calculated values of G and G′ may readily be tested.

Taking V to represent the magnetic potential at a point of the Earth's spheroidal surface where λ is the longitude, θ the colatitude, and r the distance from the Earth's centre, X, Y and Z the magnetic forces in three directions at right angles to one another, X being the force towards the north perpendicular to the Earth's radius, Y the force perpendicular to the geographical meridian towards the west, and Z the force towards the Earth's centre; also taking $\cos\theta=\mu$, we have

$$X = -\frac{dV}{rd\theta} = \frac{\sin\theta}{r}\frac{dV}{d\mu} = \frac{(1-\mu^2)^{\frac{1}{2}}}{r}.\frac{dV}{d\mu},$$

$$Y = -\frac{dV}{r\sin\theta\, d\lambda} = -\frac{(1-\mu^2)^{-\frac{1}{2}}}{r}.\frac{dV}{d\lambda},$$

$$Z = -\frac{dV}{dr},$$

if east longitudes be considered positive.

There are two systems of values of V corresponding to magnetic forces whose origin is situated inside and outside tho Earth's surface respectively, and by a convenient notation we may readily distinguish these two systems of values.

Making use of the functions denoted by H_n^m which I have above defined, and taking g_n^m and h_n^m to represent the Gaussian magnetic constants, g_n^m and h_n^m are coefficients of $\cos m\lambda$ and $\sin m\lambda$ respectively in the series of terms representing the magnetic potential.

The value of the magnetic potential V for magnetic forces whose origin is situated in the interior of the Earth is expressed by a series of terms of the form

$$\frac{1}{r^{n+1}}\left[H_n^m(g_n^m \cos m\lambda + h_n^m \sin m\lambda)\right].$$

Taking g_{-n}^m and h_{-n}^m to represent the values of the magnetic constants corresponding to this term of the series for forces situated outside the Earth's surface, the corresponding term in the magnetic potential will be

$$r^n[H_n^m(g_{-n}^m \cos m\lambda + h_{-n}^m \sin m\lambda)].$$

Hence

$$V=\Sigma\frac{1}{r^{n+1}}\left[H_n^m(g_n^m \cos m\lambda + h_n^m \sin m\lambda)\right] + \Sigma\, r^n\left[H_n^m(g_{-n}^m \cos m\lambda + h_{-n}^m \sin m\lambda)\right].$$

In the values of X, Y and Z there will be terms arising from each of these series of terms for V, and we may conveniently express them by modifying the notation in the same sense by using n subscript to refer to internal forces, and $-n$ subscript to refer to external magnetic forces, or forces whose origin is outside the Earth's surface, *i.e.* corresponding to negative powers of $\left(\frac{1}{r}\right)$.

The corresponding terms are

in the value of X,

$$\frac{1}{r^{n+2}}(1-\mu^2)^{\frac{1}{2}}\frac{dH_n^m}{d\mu}(g_n^m \cos m\lambda + h_n^m \sin m\lambda)$$

$$\text{and } r^{n-1}(1-\mu^2)^{\frac{1}{2}}\frac{dH_n^m}{d\mu}(g_{-n}^m \cos m\lambda + h_{-n}^m \sin m\lambda);$$

in the value of Y,

$$\frac{1}{r^{n+2}}(1-\mu^2)^{-\frac12}\, m\, H^m_n\, (g^m_n \sin m\lambda - h^m_n \cos m\lambda)$$

$$\text{and } r^{n-1}(1-\mu^2)^{-\frac12}\, m\, H^m_n\, (g^m_{-n} \sin m\lambda - h^m_{-n} \cos m\lambda)\,;$$

in the value of Z,

$$\frac{n+1}{r^{n+2}} H^m_n\, (g^m_n \cos m\lambda + h^m_n \sin m\lambda) \text{ and } -nr^{n-1} H^m_n\, (g^m_{-n} \cos m\lambda + h^m_{-n} \sin m\lambda$$

It is also proved that

$$(1-\mu^2)^{\frac12}\frac{dH^m_n}{d\mu} = (n-m)\, H^{m+1}_n - m\mu\, (1-\mu^2)^{-\frac12}\, H^m_n$$

$$\text{and } (1-\mu^2)^{\frac12}\frac{dH^m_n}{d\mu} = \tfrac12\,(n-m)\, H^{m+1}_n - \tfrac12\,(n+m)\, H^{m-1}_n\,;$$

and these relations are often useful in expressing the terms in the value of X.

It is found convenient to employ the notation with n and $-n$ subscript more generally to refer to internal and external forces respectively, and in this sense the following notation is employed.

Let

$$V^m_n = \frac{1}{r^{n+1}}\, H^m_n \text{ and } V^m_{-n} = r^n\, H^m_n,$$

and let

$$X^m_n = \frac{1}{r^{n+2}}\left[\tfrac12\,(n-m)\, H^{m+1}_n - \tfrac12\,(n+m)\, H^{m-1}_n\right]$$

be the coefficient of $(g^m_n \cos m\lambda + h^m_n \sin m\lambda)$ in the expression for X, the force towards the north, and let X^m_{-n} be the corresponding coefficient of $(g^m_{-n} \cos m\lambda + h^m_{-n} \sin m\lambda)$ in the expression for X arising from forces outside the Earth's surface.

$$\text{Then } X^m_{-n} = r^{n-1}\left[\tfrac12\,(n-m)\, H^{m+1}_n - \tfrac12\,(n+m)\, H^{m-1}_n\right].$$

Using the notation Y^m_n and Y^m_{-n}, and also Z^m_n and Z^m_{-n} in the same way for the forces Y and Z, we have the potential

$$V = \Sigma[V^m_n(g^m_n \cos m\lambda + h^m_n \sin m\lambda)] + \Sigma[V^m_{-n}(g^m_{-n} \cos m\lambda + h^m_{-n} \sin m\lambda)],$$
$$X = \Sigma[X^m_n(g^m_n \cos m\lambda + h^m_n \sin m\lambda)] + \Sigma[X^m_{-n}(g^m_{-n} \cos m\lambda + h^m_{-n} \sin m\lambda)],$$
$$Y = \Sigma[Y^m_n(g^m_n \sin m\lambda - h^m_n \cos m\lambda)] + \Sigma[Y^m_{-n}(g^m_{-n} \sin m\lambda - h^m_{-n} \cos m\lambda)],$$
$$Z = \Sigma[Z^m_n(g^m_n \cos m\lambda + h^m_n \sin m\lambda)] + \Sigma[Z^m_{-n}(g^m_{-n} \cos m\lambda + h^m_{-n} \sin m\lambda)].$$

Collecting coefficients of cos $m\lambda$ and sin $m\lambda$ in the values of V, X, Y and Z respectively:

The coefficient of cos $m\lambda$ in V is $\Sigma(V^m_n g^m_n + V^m_{-n} g^m_{-n})$,
,, ,, ,, X ,, $\Sigma(X^m_n g^m_n + X^m_{-n} g^m_{-n})$,
,, ,, ,, Y ,, $\Sigma(Y^m_n h^m_n + Y^m_{-n} h^m_{-n})$,
,, ,, ,, Z $\Sigma(Z^m_n g^m_n + Z^m_{-n} g^m_{-n})$.

The coefficient of sin $m\lambda$ in V is $\Sigma(V^m_n h^m_n + V^m_{-n} h^m_{-n})$,
" " " X " $\Sigma(X^m_n h^m_n + X^m_{-n} h^m_{-n})$,
" " " Y " $\Sigma(Y^m_n g^m_n + Y^m_{-n} g^m_{-n})$,
" " " Z " $\Sigma(Z^m_n h^m_n + Z^m_{-n} h^m_{-n})$,

in which n takes all integral values for a given value of m.

In a portion of his work, in which he treats of the definite integral of the product of two Legendre's coefficients, Professor Adams proves the well known formulæ, which I believe were first proved by Legendre, that when n and n_1 are different from one another

$$\int_{-1}^{1} P_n \, P_{n_1} d\mu = 0,$$

and that when $n_1 = n$,

$$\int_{-1}^{1} (P_n)^2 d\mu = \frac{2}{2n+1}.$$

He also proves that if

$$Q^m_n = (1-\mu^2)^{\frac{1}{2}} \cdot \frac{d^m P_n}{d\mu^m},$$

then
$$\int_{-1}^{1} Q^m_n \, Q^m_{n_1} \, d\mu = \frac{(n+m)\,!}{(n-m)\,!} \int_{-1}^{1} P_n \, P_{n_1} \, d\mu.$$

Hence if n and n_1 are not equal

$$\int_{-1}^{1} Q^m_n \, Q^m_{n_1} \, d\mu = 0.$$

But if $n_1 = n$, then

$$\int_{-1}^{1} (Q^m_n)^2 d\mu = \frac{(n+m)\,!}{(n-m)\,!} \cdot \frac{2}{2n+1}.$$

Hence if

$$\Pi^m_n = \left[\frac{(n-m)\,!}{(n+m)\,!}\right]^{\frac{1}{2}} Q^m_n, \text{ and } \Pi^m_{n_1} = \left[\frac{(n_1-m)\,!}{(n_1+m)\,!}\right]^{\frac{1}{2}} Q^m_{n_1},$$

it follows that

$$\int_{-1}^{1} \Pi^m_n \, \Pi^m_{n_1} \, d\mu = 0\,;$$

and, when $n = n_1$, we have

$$\int_{-1}^{1} (\Pi^m_n)^2 \, d\mu = \frac{(n-m)\,!}{(n+m)\,!} \int_{-1}^{1} (Q^m_n)^2 \, d\mu = \frac{2}{2n+1} = \int_{-1}^{1} (P_n)^2 d\mu.$$

It is also shown that

$$H^m_n = \frac{(n-m)\,!}{1\,.\,3\,.\,5\,.\,.\,.\,(2n-1)} \, Q^m_n.$$

And therefore, when n and n_1 are not equal, we have

$$\int_{-1}^{1} H^m_n \,.\, H^m_{n_1} \, d\mu = 0,$$

and, when $n_1=n$, we have

$$\int_{-1}^{1}(\mathrm{H}_n^m)^2\,.\,d\mu=\frac{(n-m)\,!\,(n+m)\,!}{[1\,.\,3\,.\,5\ldots(2n-1)]^2}\cdot\frac{2}{2n+1}.$$

From the above formulæ we see that, on a sphere of radius unity,

$$\mathrm{X}_n^m=(n-m)\,\mathrm{H}_n^{m+1}-m\mu(1-\mu^2)^{-\frac{1}{2}}\,\mathrm{H}_n^m=(1-\mu^2)^{\frac{1}{2}}\frac{d\mathrm{H}_n^m}{d\mu}$$

$$=m\mu(1-\mu^2)^{-\frac{1}{2}}\,\mathrm{H}_n^m-(n+m)\,\mathrm{H}_n^{m-1},$$

also $\mathrm{Y}_n^m=m(1-\mu^2)^{-\frac{1}{2}}\,\mathrm{H}_n^m$ and $\mathrm{Z}_n^m=(n+1)\,\mathrm{H}_n^m$.

Hence $\mu\mathrm{Y}_n^m-\mathrm{X}_n^m=(n+m)\,\mathrm{H}_n^{m-1},$

and $\mu\mathrm{Y}_n^m+\mathrm{X}_n^m=(n-m)\mathrm{H}_n^{m+1},$

also $(1-\mu^2)^{\frac{1}{2}}\mathrm{Y}_n^m=m\mathrm{H}_n^m.$

From these formulæ we find

$$\int_{-1}^{1}(\mathrm{Y}_n^m)^2d\mu+\int_{-1}^{1}(\mathrm{X}_n^m)^2d\mu=\int_{-1}^{1}(1-\mu^2)\left(\frac{d\mathrm{H}_n^m}{d\mu}\right)^2d\mu+\int_{-1}^{1}\frac{m^2}{1-\mu^2}(\mathrm{H}_n^m)^2d\mu,$$

and also

$$=\tfrac{1}{2}(n+m)^2\int_{-1}^{1}(\mathrm{H}_n^{m-1})^2d\mu+\tfrac{1}{2}(n-m)^2\int_{-1}^{1}(\mathrm{H}_n^{m+1})^2\,d\mu+m^2\int_{-1}^{1}(\mathrm{H}_n^m)^2d\mu.$$

These definite integrals reduce to

$$n(n+1)\int_{-1}^{1}(\mathrm{H}_n^m)^2d\mu.$$

Hence since $\mathrm{Z}_n^m=(n+1)\mathrm{H}_n^m$, we have

$$\int_{-1}^{1}(\mathrm{X}_n^m)^2d\mu+\int_{-1}^{1}(\mathrm{Y}_n^m)^2d\mu+\int_{-1}^{1}(\mathrm{Z}_n^m)^2d\mu=(n+1)\,(2n+1)\int_{-1}^{1}(\mathrm{H}_n^m)^2d\mu$$

$$=2\frac{(n-m)\,!\,(n+m)\,!}{[1\,.\,3\,.\,5\ldots(2n-1)]^2}\,(n+1).$$

Putting n_1 for n in the above equations we get

$$\mu\mathrm{Y}_{n_1}^m-\mathrm{X}_{n_1}^m=(n_1+m)\,\mathrm{H}_{n_1}^{m-1},$$

$$\mu\mathrm{Y}_{n_1}^m+\mathrm{X}_{n_1}^m=(n_1-m)\,\mathrm{H}_{n_1}^{m+1},$$

and $(1-\mu^2)^{\frac{1}{2}}\mathrm{Y}_{n_1}^m=m\mathrm{H}_{n_1}^m.$

Combining these formulæ we get

$$\tfrac{1}{2}(\mu\mathrm{Y}_n^m-\mathrm{X}_n^m)\,(\mu\mathrm{Y}_{n_1}^m-\mathrm{X}_{n_1}^m)+\tfrac{1}{2}(\mu\mathrm{Y}_n^m+\mathrm{X}_n^m)\,(\mu\mathrm{Y}_{n_1}^m+\mathrm{X}_{n_1}^m)+(1-\mu^2)\mathrm{Y}_n^m\mathrm{Y}_{n_1}^m$$

$$=\mathrm{X}_n^m\mathrm{X}_{n_1}^m+\mathrm{Y}_n^m\mathrm{Y}_{n_1}^m$$

$$=\tfrac{1}{2}(n+m)\,(n_1+m)\mathrm{H}_n^{m-1}\mathrm{H}_{n_1}^{m-1}+\tfrac{1}{2}(n-m)\,(n_1-m)\mathrm{H}_n^{m+1}\mathrm{H}_{n_1}^{m+1}+m^2\mathrm{H}_n^m\mathrm{H}_{n_1}^m\,;$$

hence $\displaystyle\int_{-1}^{1}\mathrm{X}_n^m\mathrm{X}_{n_1}^m d\mu+\int_{-1}^{1}\mathrm{Y}_n^m\mathrm{Y}_{n_1}^m d\mu=0,$

since we have seen that for any value of m and different values of n and n_1, the value of

$$\int_{-1}^{1} H_n^m H_{n_1}^m d\mu = 0.$$

For the same reason

$$\int_{-1}^{1} Z_n^m Z_{n_1}^m d\mu = 0.$$

Now let us consider the application of these formulæ to the determination of the numerical values of the magnetic constants of terrestrial magnetism. For a given value of μ (*i.e.* for a given latitude) we have a series of terms forming the coefficients of $\cos m\lambda$ and $\sin m\lambda$, in the values of the magnetic potential and of the magnetic forces X, Y, and Z, which are of the forms

$$\begin{gathered} a_n H_n^m + a_{n_1} H_{n_1}^m + \&c. \\ a_n X_n^m + a_{n_1} X_{n_1}^m + \&c. \\ a_n Y_n^m + a_{n_1} Y_{n_1}^m + \&c. \\ a_n Z_n^m + a_{n_1} Z_{n_1}^m + \&c. \end{gathered}$$

where a_n, a_{n_1}, &c., are the magnetic constants to be determined.

The numerical values of H_n^m, X_n^m, Y_n^m, and Z_n^m for different values of n and m must be calculated, and in any belt of latitude of breadth corresponding to the numerical value taken for $\delta\mu$, these coefficients must be equated to the values of the forces as derived from the magnetic observations taken in that belt of latitude.

The values of the magnetic forces X, Y, and Z are derived for every 10° of longitude and every 5° of latitude from the declination (δ), the dip (ι), and the horizontal force (ω), as given in the charts from which the observations are obtained. These values of the forces X, Y, and Z are analysed for belts of latitude 5° in breadth around the Earth's surface by a formula of the type $a_0 + a_1 \cos\lambda + b_1 \sin\lambda + a_2 \cos 2\lambda + b_2 \sin 2\lambda + \&c.$

If we take x_m to represent the coefficient of $\cos m\lambda$ in the expansion of the value of the force X for a given belt of latitude corresponding to the colatitude $\theta = \cos^{-1}\mu$:

then, $$a_n X_n^m + a_{n_1} X_{n_1}^m + a_{n_2} X_{n_2}^m + \&c. = x_m,$$

where x_m is derived from the observations. Similar equations, involving on one side the magnetic constants a_n, a_{n_1}, &c., and on the other the values derived from the observations, must be formed for all the successive different belts of latitude from the north pole to the south pole—*i.e.*, for all values of μ between 1 and -1.

The numerical values of X_n^m, $X_{n_1}^m$, &c., as well as the values of H_n^m (as above defined), have been determined for every degree of latitude and recorded for future use, but, in the actual determinations of the magnetic constants which have been made, belts of latitude 5° in breadth have been taken, or $\delta\theta$ has been taken as 5°, and the area of the belt is proportional to $\delta\mu$.

Supposing the observations equally distributed over the surface of the globe, or supposing the weight of any determination proportional to the surface of the corresponding element about the point of observation, then the weight of each of the above equations is proportional to $\delta\mu$, and multiplying the equation in X for each value of μ by X_n^m, and summing up the separate equations for the whole surface of the Earth, we get the final equation—

$$a_n\int_{-1}^{1}(X_n^m)^2 d\mu + a_{n_1}\int_{-1}^{1} X_n^m X_{n_1}^m d\mu + \&c. = \int_{-1}^{1} X_n^m \cdot x_m\, d\mu.$$

Similarly, the final equation for a_{n_1} is found by multiplying the above equations by $X_{n_1}^m$, $Y_{n_1}^m$, and $Z_{n_1}^m$ respectively, and we get

$$a_n\int_{-1}^{1} X_n^m X_{n_1}^m\, d\mu + a_{n_1}\int_{-1}^{1}(X_{n_1}^m)^2 d\mu + \&c. = \int_{-1}^{1} X_{n_1}^m\, x_m\, d\mu.$$

In the same way, if y_m denote the coefficient of $\sin m\lambda$ or $-\cos m\lambda$ in the value of the force Y as derived from observations, we have

$$\Sigma\,(a_n Y_n) = y_m,$$

and the final equations for finding a_n and a_{n_1} respectively will be

$$a_n\int_{-1}^{1}(Y_n^m)^2 d\mu + a_{n_1}\int_{-1}^{1} Y_n^m Y_{n_1}^m\, d\mu + \&c. = \int_{-1}^{1} Y_n^m\, y_m\, d\mu,$$

and $$a_n\int_{-1}^{1} Y_n^m Y_{n_1}^m\, d\mu + a_{n_1}\int_{-1}^{1}(Y_{n_1}^m)^2 d\mu + \&c. = \int_{-1}^{1} Y_{n_1}^m\, y_m\, d\mu.$$

Combining the final equations for a_n from X and Y together, we have

$$a_n\int_{-1}^{1}\left[(X_n^m)^2 + (Y_n^m)^2\right] d\mu = \int_{-1}^{1} X_n^m\, x_m\, du + \int_{-1}^{1} Y_n^m\, y_m\, d\mu,$$

since the coefficients of a_{n_1} and all the other terms on the left-hand side of this equation vanish when the integration is taken all over the Earth's surface.

Hence $$a_n\,.\,n(n+1)\int_{-1}^{1}(H_n^m)^2\, d\mu = \int_{-1}^{1} X_n^m\, x_m\, d\mu + \int_{-1}^{1} Y_n^m\, y_m\, d\mu\,;$$

i.e. $$a_n \times 2n(n+1)\,\frac{(n-m)\,!\,(n+m)\,!}{[1.\,3.\,5\,.\,.\,.\,(2n-1)]^2(2n+1)}$$
$$= \int_{-1}^{1} X_n^m\, x_m\, d\mu + \int_{-1}^{1} Y_n^m\, y_m\, d\mu.$$

Similarly, by putting n_1 for n, we may get the value of a_{n_1}.

In the same way the final equation for finding a_n from the equations for Z would give us

$$a_n\int_{-1}^{1}(Z_n^m)^2\, d\mu + a_{n_1}\int_{-1}^{1} Z_n^m Z_{n_1}^m\, d\mu + \&c. = \int_{-1}^{1} Z_n^m\, z_m\, d\mu\,;$$

or $$a_n(n+1)^2\int_{-1}^{1}(H_n^m)^2\, d\mu = \int_{-1}^{1} Z_n^m\, z_m\, d\mu, \text{ since } \int_{-1}^{1} Z_n^m\, Z_{n_1}^m\, d\mu = 0\,;$$

i.e. $$a_n\,2(n+1)^2\,\frac{(n-m)\,!\,(n+m)\,!}{[1.\,3.\,5\,.\,.\,.\,(2n-1)]^2(2n+1)} = \int_{-1}^{1} Z_n^m\, z_m\, d\mu.$$

If we take into account separately the parts of the magnetic force at a point due to the internal and external centres of magnetic force, the general terms of the coefficient of cos $m\lambda$ in the potential function will be of the form $\left(\frac{a_n}{r^{n+1}}+\beta_n r^n\right)H_n^m$,

and the corresponding coefficients in X, Y, and Z will be—

$$\text{in } X=\left(\frac{a_n}{r^{n+2}}+\beta_n r^{n-1}\right)\left[\tfrac{1}{2}(n-m)H_n^{m+1}-\tfrac{1}{2}(n+m)H_n^{m-1}\right];$$

$$\text{in } (1-\mu^2)^{\frac{1}{2}}Y=\left(\frac{a_n}{r^{n+2}}+\beta_n r^{n-1}\right)m\,H_n^m;$$

$$\text{in } Z=\left[\frac{(n+1)a_n}{r^{n+2}}-n\beta_n r^{n-1}\right]H_n^m.$$

If then, as before, we put $r=1$, we shall have the final equation for a_n as follows:

$$a_n\left[\int_{-1}^{1}(X_n^m)^2\,d\mu+\int_{-1}^{1}(Y_n^m)^2\,d\mu+(n+1)^2\int_{-1}^{1}(H_n^m)^2\,d\mu\right]$$
$$+\beta_n\left[\int_{-1}^{1}(X_n^m)^2 d\mu+\int_{-1}^{1}(Y_n^m)^2\,d\mu-n(n+1)\int_{-1}^{1}(H_n^m)^2\,d\mu\right]$$
$$=\int_{-1}^{1}X_n^m\,x_m\,d\mu+\int_{-1}^{1}Y_n^m\,y_m\,d\mu+(n+1)\int_{-1}^{1}H_n^m\,z_m\,d\mu,$$

where the coefficient of $\beta_n=0$.

$$\text{And } a_n\left[\int_{-1}^{1}(X_n^m)^2\,d\mu+\int_{-1}^{1}(Y_n^m)^2 d\mu-n(n+1)\int_{-1}^{1}(H_n^m)^2\,d\mu\right]$$
$$+\beta_n\left[\int_{-1}^{1}(X_n^m)^2\,d\mu+\int_{-1}^{1}(Y_n^m)^3\,d\mu+n^2\int_{-1}^{1}(H_n^m)^2\,d\mu\right]$$
$$=\int_{-1}^{1}X_n^m\,x_m\,d\mu+\int_{-1}^{1}Y_n^m\,y_m d\mu-n\int_{-1}^{1}H_n^m\,z_m\,d\mu,$$

where the coefficient of $a_n=0$.

Hence a_n and β_n are separately determined from the equations

$$2a_n(n+1)\frac{(n-m)!\,(n+m)!}{[1.\ 3.\ 5\ \ldots\ (2n-1)]^2}$$
$$=\int_{-1}^{1}X_n^m\,x_m\,d\mu+\int_{-1}^{1}Y_n^m\,y_m\,d\mu+(n+1)\int_{-1}^{1}H_n^m z_m\,d\mu$$

and

$$2\beta_n\,.\,n\frac{(n-m)!\,(n+m)!}{[1.\ 3.\ 5\ \ldots\ (2n-1)]^2}$$
$$=\int_{-1}^{1}X_n^m\,x_m\,d\mu+\int_{-1}^{1}Y_n^m y_m d\mu-n\int_{-1}^{1}H_n^m\,z_m\,d\mu.$$

Thus generally from the values of X and Y we derive

$$(a_n+\beta_n)2n(n+1)\ \frac{(n-m)!\,(n+m)!}{[1.\ 3.\ 5.\ldots(2n-1)]^2}$$
$$=(2n+1)\left[\int_{-1}^{1}X_n^m\,x_m\,d\mu+\int_{-1}^{1}Y_n^m\,y_m\,d\mu\right]$$

and from the values of Z we derive

$$\left[(n+1)\alpha_n - n\beta_n\right]\int_{-1}^{1}(\mathrm{H}_n^m)^2\,d\mu = \int_{-1}^{1}\mathrm{H}_n^m\, z_m\, d\mu$$

The above theory assumes that the integration is taken over the whole surface of the Earth, and that the observations are uniformly distributed over the Earth's surface, otherwise the coefficients of the neglected terms on the left-hand side of these equations will not vanish, and each equation may have other terms which are too important to be neglected, and so it will not be so easy to separate the magnetic constants from one another.

Let us now take into account the spheroidal figure of the Earth. Let r, θ', λ be the polar co-ordinates of a point on the spheroidal surface referred to the Earth's centre as origin and axis of figure as initial line; let θ be the geographical colatitude (the angle which the normal makes with the axis), and let $\mu = \cos\theta$ and $\mu' = \cos\theta'$.

The angle of the vertical $\psi = \theta' - \theta$.

The values of the sines and cosines of these angles for values of θ differing by 1° from 0° to 90° have been computed, the eccentricity e of the elliptic section in the plane of the meridian being derived from Bessel's dimensions of the Earth as given in Encke's tables in the 'Berliner Jahrbuch,' 1852.

The expressions for the magnetic potential and for the magnetic forces X, Y, and Z, in terms of the Gaussian magnetic constants g_n^m, h_n^m will be of the same form as those given above (see p. 4). Where X is the total force towards the north perpendicular to the Earth's radius, Y the total force perpendicular to the geographical meridian towards the west, Z the force towards the Earth's centre, or

$$\mathrm{X} = -\frac{d\mathrm{V}}{r\,d\theta'},\ \mathrm{Y} = -\frac{1}{r\sin\theta'}\cdot\frac{d\mathrm{V}}{d\lambda},\ \text{and } \mathrm{Z} = -\frac{d\mathrm{V}}{dr}$$

(east longitudes being considered positive).

If X′ be the horizontal force in the meridian towards the north,

Y′ the horizontal force perpendicular to the meridian towards the west,

Z′ the vertical downward force on the spheroidal surface of the Earth,

then

$$\mathrm{X}' = \mathrm{X}\cos\psi + \mathrm{Z}\sin\psi$$
$$\mathrm{Y}' = \mathrm{Y}$$
$$\mathrm{Z}' = -\mathrm{X}\sin\psi + \mathrm{Z}\cos\psi.$$

We may conveniently denote the values of the coefficients of $g_n^m \cos m\lambda$ and $h_n^m \sin m\lambda$ in the potential function and in the forces X′, Y′, and Z′ by the symbols V'^m_n, X'^m_n, Y'^m_n, and Z'^m_n respectively.

If r be the radius vector, $\mu = \cos\theta$ and $\mu' = \cos\theta'$,

then

$$\mathrm{V}'^m_n = \frac{1}{r^{n+1}}\mathrm{H}'^m_n,\ \text{and } \mathrm{V}'^m_{-n} = r^n\,\mathrm{H}'^m_{-n},$$

H'^m_n being the same function of μ' that H^m_n is of μ.

The expressions for the magnetic forces on the spheroidal surface of the Earth will be as follows:—

Taking α_n and β_n to represent magnetic constants depending on internal and external sources of magnetic force respectively, the coefficient of cos $m\lambda$ in the general term of the potential function V is

$$\left(\frac{\alpha_n}{r^{n+1}} + \beta_n r^n\right) H'^m_n.$$

The coefficient of cos $m\lambda$ in the general terms of the forces X, Y, and Z are—

for X, $$\left(\frac{\alpha_n}{r^{n+2}} + \beta_n\, r^{n-1}\right)\,(1-\mu'^2)^{\frac{1}{2}}\,\frac{d\,H'^m_n}{d\mu'},$$

for Y, $$\left(\frac{a^n}{r^{n+2}} + \beta_n\, r^{n-1}\right)\, m(1-\mu'^2)^{-\frac{1}{2}}\,H'^m_n,$$

for Z, $$\left(\frac{\alpha_n(n+1)}{r^{n+2}} - \beta_n\,.\,n\,.\,r^{n-1}\right)\,H'^m_n.$$

In the following investigation of the coefficients of cos $m\lambda$, &c., in which m remains the same, whilst n may have different values, it will be convenient to denote H^m_n by H_n, X^m_n by X_n, &c. We will denote the corresponding quantities on the spheroid by H'_n, X'_n, &c., and regard them as functions of μ', θ' being the geocentric colatitude.

Taking the equatorial radius $=1$, δS an element of the Earth's surface and e the eccentricity, and taking into account only the terms to the order e^2, we have $\frac{1}{r^2} = 1 + e^2\mu^2$, $\sin\psi = e^2\mu(1-\mu^2)^{\frac{1}{2}}$ to the order e^2,

$$\mu' = \cos\theta - \sin\theta\,\sin\psi = \mu - e^2\mu(1-\mu^2)\quad \frac{d\mu'}{d\mu} = 1 - e^2(1-3\mu^2),$$

and $$\frac{dS}{d\mu'} = -\,2\pi(1-e^2\mu^2)\,;$$

also $$\frac{1}{r^{n+2}} = 1 + \frac{n+2}{2}\,e^2\mu^2, \text{ and } r^{n-1} = 1 - \frac{n-1}{2}\,e^2\mu^2.$$

Regarding H'_n and $\frac{d\,H'_n}{d\mu'}$, &c., as functions of μ', we have by Taylor's theorem—

$$H'_n = H_n - e^2\mu(1-\mu^2)\,\frac{d\,H_n}{d\mu} \text{ to the order } e^2,$$

and $$\frac{d\,H'_n}{d\mu'} = \frac{d\,H_n}{d\mu} - e^2\mu(1-\mu^2)\,\frac{d^2\,H_n}{d\mu^2},$$

from which we derive the value of X_n for the spheroidal surface—

$$X_n = (1-\mu'^2)^{\frac{1}{2}}\,\frac{d\,H'_n}{d\mu'}$$

$$= (1-\mu^2)^{\frac{1}{2}}\frac{d\,H_n}{d\mu}\,(1-e^2\mu^2) + e^2\mu\,(1-\mu^2)^{\frac{1}{2}}\left[n(n+1) - \frac{m^2}{1-\mu^2}\right]H_n.$$

If now we substitute the values of X, Y, and Z in terms of H'_n, $\frac{d\,H'_n}{d\mu'}$, &c., in the equations—

$$X' = X\cos\psi + Z\sin\psi,$$
$$Y' = Y,$$
$$Z' = -X\sin\psi + Z\cos\psi,$$

the expressions for the magnetic forces become—

$$X' = \left(\frac{a_n}{r^{n+2}} + \beta_n r^{n-1}\right) \frac{d\,H'_n}{d\mu'} (1-\mu^2)^{\frac{1}{2}} \cos\psi$$

$$+ \left[\frac{(n+1)a_n}{r^{n+2}} - n\,\beta_n r^{n-1}\right] H'_n \sin\psi + \text{similar terms},$$

$$Y' = \left(\frac{a_n}{r^{n+2}} + \beta_n r^{n-1}\right) m H'_n (1-\mu^2)^{-\frac{1}{2}} + \text{similar terms},$$

$$Z' = -\left(\frac{a_n}{r^{n+2}} + \beta_n r^{n-1}\right) \frac{d\,H'_n}{d\mu'} (1-\mu^2)^{\frac{1}{2}} \sin\psi$$

$$+ \left[\frac{(n+1)a_n}{r^{n+2}} - n\,\beta_n r^{n-1}\right] H'_n \cos\psi + \text{similar terms}.$$

In these expressions for the magnetic forces the values of H'_n, $\frac{d\,H'_n}{d\mu'}$, &c., in terms of H_n, $\frac{d\,H_n}{d\mu}$, &c., are substituted for each belt of latitude, and these theoretical expressions derived from the potential function for a given belt of latitude, and containing the magnetic constants, are equated to the corresponding coefficients derived from the magnetic observations taken in that belt of latitude.

In the case of the spheroid, as in the case of the sphere, the values of the forces X, Y, and Z derived for every 10° of longitude from the observations of declination, inclination, and horizontal force are analysed for belts of latitude 5° in breadth around the Earth's surface by a formula of the type—

$$a_0 + a_1 \cos\lambda + b_1 \sin\lambda + a_2 \cos 2\lambda + b_2 \sin 2\lambda + \&c.,$$

and the coefficients of $\cos m\lambda$, $\sin m\lambda$, in this expansion are equated respectively to the coefficients of $\cos m\lambda$, and $\sin m\lambda$ in the expansion in terms of the potential function and magnetic constants as given above: thus for the force X, if a_n, a_{n_1}, a_{n_2} &c., stand for the magnetic constants, and if x_m be the coefficient of $\cos m\lambda$ as derived directly from the observations,

$$\text{then } a_n\, X'^m_n + a_{n_1}\, X'^m_{n_1} + a_{n_2}\, X'^m_{n_2} + \&c., = x_m,$$

and similar equations are obtained from the expressions for the forces Y′ and Z′.

The values X'^m_n, Y'^m_n, and Z'^m_n, taken in these equations, are the values derived for the spheroidal surface of the Earth from the potential function, and these equations not only include the magnetic constants which were determined by Gauss, of the class indicated by a in the above equation, but they also include magnetic constants which may be spoken of for distinction as the β class, *i.e.* including those forces which depend upon sources outside the surface of the Earth.

The full values, then, of the coefficients of the magnetic constants will be of the following form:

For the α class—

$$X'^m_n = \frac{1}{r^{n+2}}\left[\tfrac{1}{2}(n-m)H'^{m+1}_n - \tfrac{1}{2}(n+m)H'^{m-1}_n\right]\cos\psi + \frac{n+1}{r^{n+2}}H'^m_n \sin\psi,$$

$$Y'^m_n = \frac{1}{r^{n+2}}\left[m(1-\mu'^2)^{-\frac{1}{2}}\,H'^m_n\right],$$

$$Z'^m_n = -\frac{1}{r^{n+2}}\left[\tfrac{1}{2}(n-m)H'^{m+1}_n - \tfrac{1}{2}(n+m)H'^{m-1}_n\right]\sin\psi + \frac{n+1}{r^{n+2}}H'^m_n \cos\psi.$$

For the β class, which may be denoted by X'^m_{-n}, Y'^m_{-n}, and Z'^m_{-n},

$$X'^m_{-n} = r^{n-1}[\tfrac{1}{2}(n-m)H'^{m+1}_n - \tfrac{1}{2}(n+m)H'^{m-1}_n]\cos\psi - nr^{n-1}\,H'^m_n \sin\psi,$$

$$Y'^m_{-n} = r^{n-1}[m(1-\mu'^2)^{-\frac{1}{2}}H'^m_n],$$

$$Z'^m_{-n} = -r^{n-1}[\tfrac{1}{2}(n-m)H'^{m+1}_n - \tfrac{1}{2}(n+m)H'^{m-1}_n]\sin\psi - nr^{n-1}\,H'^m_n \cos\psi.$$

The numerical values of these expressions for all values of m from 0 to 10, and for all values of n from 1 to 10 for the spheroidal surface of the Earth, have been calculated from the values of μ for every 5° of colatitude, and form the coefficients of the magnetic constants g^m_n, h^m_n, and g^m_{-n}, h^m_{-n} of the α and β class respectively in the equations for the determination of these constants.

The number of magnetic constants contained in these equations which have been completely formed is thus 120 of each class, or 240 magnetic constants in all, in place of the 24 constants of the α class which were previously determined by Gauss.

Regarding the Earth as a spheroid of revolution, the values of $\mu' = \cos\theta'$, where θ' is the geocentric colatitude, have been determined for every 5° of geographical colatitude. Also the values of $\cos\psi$, $\sin\psi$, $\frac{a}{r}$, G'^m_n, and H'^m_n have been calculated for every 5° of geographical colatitude (*i.e.* for the above values of μ') for all values of n and m from 0 to 10.

The weights of the observations of the magnetic elements for these belts of latitude have also been determined on the assumption that the weight is proportional to the area of the corresponding portion of the Earth's surface.

The values of H'^m_n as a function of the geocentric colatitude having been determined for every 5° of geographical colatitude on the spheroid, we next proceed to determine from them the values of X'^m_n, X'^m_{-n}, Y'^m_n, Y'^m_{-n}, Z'^m_n, and Z'^m_{-n}, $X'^m_n(=X^m_n\cos\psi + Z^m_n\sin\psi)$, X'^m_{-n}, $Z'^m_n(=-X^m_n\sin\psi + Z^m_n\cos\psi)$ and Z'^m_{-n}, the resolved parts of the expressions for the horizontal and vertical forces in the plane of the meridian on the spheroid.

These values are required in the formation of the equations of condition, and their numerical values are calculated for every 5° of geographical colatitude as well as for the Equator and the Poles. These values of X'^m_n, &c., have been calculated and recorded in tables for all values of n and m from 0 to 10, and have been employed as the theoretical coefficients of the magnetic constants g^m_n, h^m_n, &c., in the equations of condition.

Formation of the Equations of Condition.

When $n-m$ is even, the value of X^m_n contains only odd powers of μ, and the values of Y^m_n and Z^m_n only even powers, and similarly when $n-m$ is odd, the value of X^m_n contains only even powers of μ, and the values of

Y^m_n and Z^m_n only odd powers. Hence, if the coefficient of cos $m\lambda$ in either of the quantities X, Y, Z be denoted by a_m and the coefficient of sin $m\lambda$ by b_m for a given north latitude, and if a'_m, b'_m denote the similar quantities for the corresponding south latitude, then we have, when $n-m$ is even,

$$\tfrac{1}{2}(a_m-a'_m)=\Sigma(X^m_n g^m_n+X^m_{-n}g^m_{-n}), \text{ and } \tfrac{1}{2}(b_m-b'_m)=\Sigma(X^m_n h^m_n+X^m_{-n}h^m_{-n}),$$
$$\tfrac{1}{2}(b_m+b'_m)=\Sigma(Y^m_n g^m_n+Y^m_{-n}g^m_{-n}), \text{ and } -\tfrac{1}{2}(a_m+a'_m)=\Sigma(Y^m_n h^m_n+Y^m_{-n}h^m_{-n}),$$
$$\tfrac{1}{2}(a_m+a'_m)=\Sigma(Z^m_n g^m_n+Z^m_{-n}g^m_{-n}), \text{ and } \tfrac{1}{2}(b_m+b'_m)=\Sigma(Z^m_n h^m_n+Z^m_{-n}h^m_{-n}),$$

and when $n-m$ is odd

$$\tfrac{1}{2}(a_m+a'_m)=\Sigma(X^m_n g^m_n+X^m_{-n}g^m_{-n}), \text{ and } \tfrac{1}{2}(b_m+b'_m)=\Sigma(X^m_n h^m_n+X^m_{-n}h^m_{-n}),$$
$$\tfrac{1}{2}(b_m-b'_m)=\Sigma(Y^m_n g^m_n+Y^m_{-n}g^m_{-n}), \text{ and } -\tfrac{1}{2}(a_m-a'_m)=\Sigma(Y^m_n h^m_n+Y^m_{-n}h^m_{-n}),$$
$$\tfrac{1}{2}(a_m-a'_m)=\Sigma(Z^m_n g^m_n+Z^m_{-n}g^n_{-n}), \text{ and } \tfrac{1}{2}(b_m-b'_m)=\Sigma(Z^m_n h^m_n+Z^m_{-n}h^m_{-n}).$$

Hence the equations for the quantities h^m_n and h^m_{-n} will be found from the equations for g^m_n and g^m_{-n}, when $n-m$ is even, by substituting

$\tfrac{1}{2}(b_m-b'_m)$ for $\tfrac{1}{2}(a_m-a'_m)$ in the equations for X,
$-\tfrac{1}{2}(a_m+a'_m)$ for $\tfrac{1}{2}(b_m+b'_m)$ in the equations for Y,
and $\tfrac{1}{2}(b_m+b'_m)$ for $\tfrac{1}{2}(a_m+a'_m)$ in the equations for Z.

And similarly the equations for h^m_n and h^m_{-n} will be found from the equations for g^m_n and g^m_{-n}, when $n-m$ is odd, by substituting

$\tfrac{1}{2}(b_m+b'_m)$ for $\tfrac{1}{2}(a_m+a'_m)$ in the equations for X,
$-\tfrac{1}{2}(a_m-a'_m)$ for $\tfrac{1}{2}(b_m-b'_m)$ in the equations for Y,
and $\tfrac{1}{2}(b_m-b'_m)$ for $\tfrac{1}{2}(a_m-a'_m)$ in the equations for Z.

In the first solution of the equations, the *absolute terms* (*i.e.* the terms derived from the *observed* values of the magnetic elements) are taken from Sabine's magnetic charts for the period about 1845, as published in the 'Philosophical Transactions of the Royal Society.' In the second solution, the observed values of the magnetic elements are taken from the Admiralty charts for 1880 prepared by Captain Creak, kindly lent by the Lords of the Admiralty.

The values of X, Y and Z are calculated for every 10° of longitude and every 5° of latitude from the declination (δ), the dip (ι), and the horizontal force (ω) as given in the charts. Then the values of X, Y and Z are analysed for belts of latitude 5° in breadth around the earth by the formula

$$a_0+a_1\cos\lambda+b_1\sin\lambda+a_2\cos 2\lambda+b_2\sin 2\lambda\ +\ \&c.$$

The values of these coefficients for the different belts of latitude were obtained and tabulated. Then if a_m and b_m denote the values of two of these coefficients for a given northern latitude, and a'_m, b'_m the corresponding values for an equal southern latitude, then the values of $\tfrac{1}{2}(a_m+a'_m)$, $\tfrac{1}{2}(a_m-a'_m)$, $\tfrac{1}{2}(b_m+b'_m)$, and $\tfrac{1}{2}(b_m-b'_m)$ and of their logarithms are determined. The values of these quantities are determined for each of the periods for which the magnetic constants are required.

Each system of equations of condition will involve a single value of m combined with all even values of n, or with all odd values of n.

There will be one system for the coefficients X^m_n, X^m_{-n}, another for the coefficients Y^m_n, Y^m_{-n} and a third for the coefficients Z^m_n, Z^m_{-n}.

Each belt of latitude will contribute an equation to each system. The belts, 5° in breadth, are distinguished by the letters (a), (b), (c), &c., starting from $87\frac{1}{2}°$ N. latitude.

Then if P, Q, R be quantities given by observation we shall have equations of the form

$$\begin{aligned} X_2^m g_2^m + X_{-2}^m g_{-2}^m + X_4^m g_4^m + X_{-4}^m g_{-4}^m + \&c. &= P, \\ Y_2^m g_2^m + Y_{-2}^m g_{-2}^m + Y_4^m g_4^m + Y_{-4}^m g_{-4}^m + \&c. &= Q, \\ Z_2^m g_2^m + Z_{-2}^m g_{-2}^m + Z_4^m g_4^m + Z_{-4}^m g_{-4}^m + \&c. &= R, \end{aligned}$$

for even values of n, and similar equations with other quantities P′, Q′, R′, given by observation, for odd values of n.

Thus for latitude 60°, the set (f) will furnish the three following equations to the respective systems X, Y, Z, corresponding to $m=4$,

[1]

$$\begin{aligned} -[9{\cdot}6479108]\, g_4^4 - [9{\cdot}6397698]\, g_{-4}^4 - [9{\cdot}3739435]\, g_6^4 - [9{\cdot}3627519]\, g_{-6}^4 &= P, \\ [9{\cdot}7120302]\, g_4^4 + [9{\cdot}7022392]\, g_{-4}^4 + [9{\cdot}5314878]\, g_6^4 + [9{\cdot}5173452]\, g_{-6}^4 &= Q, \\ [9{\cdot}5118188]\, g_4^4 - [9{\cdot}4012092]\, g_{-4}^4 + [9{\cdot}4766723]\, g_6^4 - [9{\cdot}3934121]\, g_{-6}^4 &= R; \end{aligned}$$

and the three following to the similar systems corresponding to odd values of n,

$$\begin{aligned} -[9{\cdot}5471920]\, g_5^4 - [9{\cdot}5374280]\, g_{-5}^4 - [9{\cdot}1267947]\, g_7^4 - [9{\cdot}1145742]\, g_{-7}^4 &= P', \\ [9{\cdot}6499180]\, g_5^4 + [9{\cdot}6379512]\, g_{-5}^4 + [9{\cdot}3653414]\, g_7^4 + [9{\cdot}3490233]\, g_{-7}^4 &= Q', \\ [9{\cdot}5284778]\, g_5^4 - [9{\cdot}4344144]\, g_{-5}^4 + [9{\cdot}3682450]\, g_7^4 - [9{\cdot}2923736]\, g_{-7}^4 &= R'. \end{aligned}$$

These *equations of condition* are multiplied by the weights w_a, w_b, &c., of the observations for their respective belts of latitude, the weight of each equation from the set (s) corresponding to $2\frac{1}{2}°$ on each side of the equator being $\frac{1}{2}\, w_s$. Then the *final* equation for each magnetic constant g_n^m is formed by multiplying each equation so formed by the coefficient of g_n^m in the corresponding equation of condition, and adding together the resulting coefficients of g_n^m from the different sets (s), (r), (q), &c.

To form this final equation for each constant multiply each equation of condition by $\sqrt{\text{weight}}$ and then multiply the resulting equation by the coefficient of that constant g_n^m in it which has to be determined. Then integrating or adding up the coefficients of the several magnetic constants, we get the equation in the form

$$\Sigma[(X_n^m)^2 w]\, g_n^m + \Sigma[X_n^m\, X_{-n}^m w]\, g_{-n}^m + \&c. = \Sigma[X_n^m .\ w.\, P],$$

with similar equations for Y and Z for even values of n, and with other similar equations with P′, Q′, R′, for odd values of n.

We shall have a separate final equation for each value of n; thus the final equation for $g_{n_1}^m$ is

$$\Sigma[X_n^m X_{n_1}^m w\, g_n^m + X_{-n}^m\, X_{n_1}^m\, w\, g_{-n}^m + (X_{n_1}^m)^2 w\, g_{n_1}^m + \&c.] = X_{n_1}^m\, w\, P, \quad (3)$$

for even values of n_1, and a similar expression with P′ instead of P for odd values of n_1.

Then adding up, for any constant $g_{n_1}^m$, the coefficients in the final

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[1] Where [9·6479108] is employed to express the number of which 9·6479108 is the logarithm.

equations for all the different belts of latitude we have the final equation from the series (X), which may be represented by the form

$$\Sigma[X^m_n X^m_{n_1}.w]g^m_n+\Sigma[X^m_{-n} X^m_{n_1}.w]g^m_{-n}+\Sigma[(X^m_{n_1})^2 w]g^m_{n_1}+\&c.=\Sigma[X^m_{n_1}.w.P] \quad (4)$$

Equations similar to the above will be derived from the series (Y) and from the series (Z).

These equations may be solved separately, and the values of the magnetic constants determined from each series, taking series (X), series (Y), and series (Z) separately.

The series (X) and the series (Y) may also be conveniently combined into one equation in the same way as the above equations for different latitudes in X have been combined, in which case the coefficient of g^m_n in the final equation for $g^m_{n_1}$ will be

$$\Sigma[X^m_n X^m_{n_1}.w]+\Sigma[Y^m_n Y^m_{n_1}.w],$$

and the coefficient of $g^m_{n_1}$ in the final equation for $g^m_{n_1}$ will be

$$\Sigma(X^m_{n_1})^2w+\Sigma(Y^m_{n_1})^2w.$$

We have seen above that in the case of a *sphere* the coefficients of each of the magnetic constants in this equation (4), except the coefficient of $g^m_{n_1}$, will vanish.

The corresponding coefficients on the spheroid will be small, depending on the value of the square of the eccentricity; but this will only be the case when the summation is taken all over the surface.

The right-hand side of the equation becomes under these conditions $\Sigma[X^m_{n_1}.P.w]+\Sigma[Y^m_{n_1}.Q.w]$ for the equation of $g^m_{n_1}$ in turn for all values of n_1. Hence when the successive belts are sufficiently near together the coefficient of $(g^m_n+g^m_{-n})$ in the final equation for g^m_n is approximately

$$n(n+1)\int_{-1}^{1}(H^m_n)^2\,d\mu$$

or,

$$=\frac{n(n+1)}{2n+1}\times 2\frac{(n-m)!\,(n+m)!}{[1.3.5\ldots(2n-1)]^2};$$

and, as before, the right-hand side of the equation becomes

$$\int_{-1}^{1}X^m_n.P.d\mu+\int_{-1}^{1}Y^m_n.Q.d\mu.$$

In the present state of our knowledge as to the values of P, Q, R, &c., which are derived from the observations of the magnetic elements, the charts giving the values of those elements are exceedingly defective for our purpose, and the observations taken in high latitudes are not sufficiently numerous and appear to be doubtful—no great reliance can be placed upon them. Under these circumstances we propose to solve these equations, taking into account the data as derived from magnetic observations over the portion of the surface of the Earth between latitudes $67\frac{1}{2}$° N. and $67\frac{1}{2}$° S., taking only the equations of condition for belts between these latitudes, and taking only those terms in these equations for values of m from 0 to 6 and for values of n from 1 to 6 inclusive. These equations will give values for 48 constants, and no equation will contain more than three unknown quantities.

The coefficients $\Sigma[X_n^m X_{n_1}^m.w]$, &c., on the left-hand side of the above equations of condition will be the same for g_n^m and for h_n^m, but the right-hand sides of the equations $\Sigma[X_n^m w\,P]$, &c., the *absolute* terms derived from the observations, will be different. Hence the equations for solution may be conveniently arranged as follows.

From (X) taken separately

$$\Sigma[X_n^m X_{n_1}^m.w]g_n^m+\Sigma[(X_{n_1}^m)^2w]g_{n_1}^m+\&c.=\begin{pmatrix}\text{absolute term}\\ \text{for } g_{n_1}^m\end{pmatrix}$$

$$\text{and } \Sigma[X_n^m X_{n_1}^m.w]h_n^m+\Sigma[(X_{n_1}^m)^2w]h_{n_1}^m+\&c.=\begin{pmatrix}\text{absolute term}\\ \text{for } h_{n_1}^m\end{pmatrix}.$$

From the series for (X) combined with the series for (Y) we may also solve the equations, of which the type will be as follows:

$$\begin{aligned}&\{\Sigma[X_n^m X_{n_1}^m.w]+\Sigma[Y_n^m Y_{n_1}^m.w]\}g_n^m\\ &\quad+\{\Sigma[(X_{n_1}^m)^2w]+\Sigma[(Y_{n_1}^m)^2w]\}g_{n_1}^m+\&c.=\begin{pmatrix}\text{absolute term}\\ \text{for } g_{n_1}^m\end{pmatrix}\\ \text{and }&\{\Sigma[(X_n^m X_{n_1}^m w]+\Sigma[Y_n^m Y_{n_1}^m w]\}h_n^m\\ &\quad+\{\Sigma[(X_{n_1}^m)^2w]+\Sigma[(Y_{n_1}^m)^2w]\}h_{n_1}^m+\&c.=\begin{pmatrix}\text{absolute term}\\ \text{for } h_{n_1}^m\end{pmatrix}\end{aligned}$$

the absolute terms being derived in this case from the series for (X) and for (Y) combined. In general the values of the same constants derived from these equations will differ somewhat from one another, and the question arises which solution will give the truer value.

Probably in the present state of our knowledge of the magnetic elements over the surface of the Earth the equations derived from the series for (X), (Y) and (Z) combined, for all latitudes from 67½° S. to 67½° N., will give the most trustworthy values of the constants of terrestrial magnetism, that we may hope to attain from any magnetic charts derived from observations previous to the Admiralty Charts of 1880.

Let us illustrate the mode of solving these final equations by taking the case given above, in which $m=4$ and n odd, taking the equations of condition up to latitude 77½° inclusive, and combining the equations for X, Y and Z, supposing the constant corresponding to negative values of n to be non-existent. We will include the terms involving $n=7$.

The coefficients for g_5^4 and h_5^4 being the same, we may take α_5^4 to stand for either (1) g_5^4 or (2) h_5^4, taking the *absolute* term for g_5^4 in the first case and h_5^4 in the second, and the final equations for g_5^4 and h_5^4 for the period 1845 may be written thus:

From

$$\begin{array}{llcl} & & \text{(for } g_5^4) & \text{(for } h_5^4)\\ \text{(X)} & 3{\cdot}4034960\ \alpha_5^4-{\cdot}3898572\ \alpha_7^4= & {\cdot}2416593 \text{ or} & -{\cdot}0159063.\\ \text{(Y)} & 9{\cdot}4158541\ \alpha_5^4+{\cdot}4092903\ \alpha_7^4= & {\cdot}0589245 \text{ or} & +{\cdot}3418323.\\ \text{(Z)} & 15{\cdot}3871472\ \alpha_5^4+{\cdot}0223528\ \alpha_7^4= & {\cdot}4657356 \text{ or} & +{\cdot}1824818.\end{array}$$

Adding these together, we have

$$28{\cdot}2064973\ \alpha_5^4+{\cdot}0417859\ \alpha_7^4={\cdot}7663194 \text{ or } {\cdot}5084078 \qquad (a).$$

Similarly the final equations for α_7^4 and h_7^4 may be written thus:

$$\begin{array}{lll} \text{(X)} & -{\cdot}3898572\ \alpha_5^4+{\cdot}2637326\ \alpha_7^4={\cdot}0204205 \text{ or} & {\cdot}0140404.\\ \text{(Y)} & {\cdot}4092903\ \alpha_5^4+{\cdot}3081774\ \alpha_7^4={\cdot}0454171 \text{ or} & {\cdot}0373065.\\ \text{(Z)} & {\cdot}0223528\ \alpha_5^4+{\cdot}6536612\ \alpha_7^4={\cdot}0056358 \text{ or} & {\cdot}0882180.\end{array}$$

Adding these together, we have

$$\cdot0417859\, a_5^4 + 1\cdot2255712\, a_7^4 = \overset{(\text{for } g_5^4)}{\cdot0714734} \text{ or } \overset{(\text{for } h_5^4)}{\cdot1395649} \qquad (\beta).$$

Eliminating a_5^4 from the equations (α) and (β) we have

$$1\cdot2255093\, a_7^4 = \cdot0703382 \text{ or } \cdot1388117.$$

[1] Hence $g_7^4 = \cdot0573951$, and $h_7^4 = \cdot1132686$.

Substituting in the first equation, we get

$$g_5^4 = \cdot0270832 \text{ and } h_5^4 = \cdot0178567.$$

Hence it appears to be important to take g_7^4 and h_7^4 into account, as they are larger than g_5^4 and h_5^4.

Similarly in solving the equations with $m=4$ and n even, it is found that

$$g_4^4 = \cdot0029684,\ h_4^4 = \cdot0217744$$
$$g_6^4 = \cdot0642604,\ h_6^4 = \cdot0603230.$$

So that g_6^4 and h_6^4 are more important than g_4^4 and h_4^4.

The relative importance of magnetic constants of different orders is well shown by the solution of the final equations for h_3^2, h_5^2 and h_7^2 for the period 1880. Keeping in the terms containing h_7^2, the final equations derived by combining the equations for X, Y and Z are

$$24\cdot1400624\, h_3^2 - \cdot2579706\, h_5^2 - \cdot1213933\, h_7^2 = \cdot19111,$$
$$-\cdot2579706\, h_3^2 + 2\cdot1784697\, h_5^2 - \cdot0719819\, h_7^2 = \cdot13841,$$
$$-\cdot1213933\, h_3^2 - \cdot0719819\, h_5^2 + \cdot1887180\, h_7^2 = -\cdot02852.$$

The solution of these equations gives the values

$$h_3^2 = \cdot00794,\ h_5^2 = \cdot06041,\ h_7^2 = -\cdot12298 \text{ British units.}$$

Converting these into c.g.s. units we get

$$h_3^2 = \cdot000366,\ h_5^2 = \cdot0027855,\ h_7^2 = -\cdot00567.$$

Comparison with the tables shows that the effect of keeping in the constant h_7^2 is to make a considerable change in the values of the constants h_3^2 and h_5^2.

The corresponding equations for g_3^2, g_5^2 and g_7^2 are

$$-14\cdot62295 = 24\cdot1400624\, g_3^2 - \cdot2579706\, g_5^2 - \cdot1213933\, g_7^2$$
$$-1\cdot11044 = -\cdot2579706\, g_3^2 + 2\cdot1784697\, g_5^2 - \cdot0719819\, g_7^2$$
$$\cdot05785 = -\cdot1213933\, g_3^2 - \cdot0719819\, g_5^2 + \cdot1887180\, g_7^2,$$

and the solution of these equations gives the values

$$g_3^2 = -\cdot613670,\ g_5^2 = -\cdot592789,\ g_7^2 = -\cdot314308 \text{ British units, or}$$
$$g_3^2 = -\cdot028295,\ g_5^2 = -\cdot027332,\ g_7^2 = -\cdot014492 \text{ c.g.s. units.}$$

These values of g_3^2 and g_5^2 do not differ much from the values previously obtained, which are given in the following table.

Let us further illustrate the mode of solving these final equations by taking the case of $m=0$ and n odd.

Since the observations of magnetic elements in high latitudes appear to be doubtful, we will form the equations of condition, taking into account the data only up to 67½° N. and S. latitudes.

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[1] The two extra magnetic constants g_7^4 and h_7^4 here determined make up the number of constants which have been determined to 50.

The formation of the final equations for g_1^0, g_3^0 and g_5^0 will then be as follows:
from equations for (X)

$$53{\cdot}575026 = 7{\cdot}6331952\, g_1^0 - {\cdot}1138565\, g_3^0 - {\cdot}0886747 g_5^0,$$
$$-2{\cdot}456863 = -{\cdot}1138565\, g_1^0 + 2{\cdot}8880836\, g_3^0 - {\cdot}1765112\, g_5^0,$$
$$-{\cdot}4538875 = -{\cdot}0886747\, g_1^0 - {\cdot}1765112\, g_3^0 + {\cdot}3955108\, g_5^0;$$

from equations for (Z)

$$85{\cdot}065860 = 12{\cdot}0636234\, g_1^0 - 2{\cdot}1413469\, g_3^0 - {\cdot}7000106\, g_5^0,$$
$$-16{\cdot}292662 = -2{\cdot}1413469\, g_1^0 + 2{\cdot}7856531\, g_3^0 - {\cdot}4744250\, g_5^0,$$
$$-4{\cdot}6678164 = -{\cdot}7000106\, g_1^0 - {\cdot}4744250\, g_3^0 + {\cdot}4394974\, g_5^0.$$

Solving the equations for (X) we get

$$g_1^0 = 7{\cdot}01229,\ g_3^0 = -{\cdot}56367,\ g_5^0 = {\cdot}17302.$$

These values agree almost exactly with those found from the whole of the equations for (X) up to latitude 77½°.
Solving the equations for (Z) we get

$$g_1^0 = 6{\cdot}951666,\ g_3^0 = -{\cdot}524544, \text{ and } g_5^0 = -{\cdot}11476.$$

These values agree very closely with those found from the whole of the equations for (Z) to the same latitude.

The values of g_1^0 and g_3^0 agree fairly well with those found from the equations for (X), but the values of g_5^0 have opposite signs. Probably the neglected term in g_7^0 may have some influence on this result.

Taking the negative values of n into account, let us find *approximately* what values of g^0_{-1}, g^0_{-3}, g^0_{-5} will bring the two sets of results into harmony.

This may be done by substituting $g_n^0 + g^0_{-n}$ for g_n^0 in the (X) equations, and $g_n^0 - \frac{n}{n+1} g^0_{-n}$ for g_n^0 in the (Z) equations.

Hence we get

$$g_1^0 = 6{\cdot}971874,\ g^0_{-1} = {\cdot}040416,\ g_3^0 = -{\cdot}541312,\ g^0_{-3} = -{\cdot}022358,$$
$$g_5^0 = {\cdot}01605, \text{ and } g^0_{-5} = {\cdot}15697.$$

Hence the constant g^0_{-5} seems to be of great importance.

The values found for the two first of the above constants are, in in British units,

by Gauss	by Erman
$g_1^0 = 7{\cdot}0155$	$g_1^0 = 6{\cdot}9417$
$g_3^0 = -{\cdot}1430.$	$g_3^0 = -{\cdot}4069.$

The values of these constants, derived from the above series of equations for (X), (Y) and (Z), combined for all latitudes from 67½° S. to 67½° N., are $g_1^0 = 6{\cdot}98081$ and $g_3^0 = -{\cdot}523986$ for the period (1842–45) from Sabine's charts.

The values derived for the above constants from the above equations of condition, taking m from 0 to 4 and n from 1 to 4 only and neglecting the other terms (*i.e.* taking those only which were determined by Gauss), are $g_1^0 = 6{\cdot}9777$ and $g_3^0 = -{\cdot}5310$ for the same period.

The values of the constants given in the two following tables are derived from the combined equations for (X), (Y) and (Z) to equations (e) inclusive (*i.e.* between latitudes 67½° S. and 67½° N.), supposing the constants corresponding to negative values of n to be non-existent.

The second of these tables gives the values of the constants when we include in the equations only those twenty-four constants which are taken into account by Gauss himself. This table also includes the values (in British units) of these constants as determined by Gauss, and also by Erman. (The sign + is understood when no sign is given.)

Table of the Values of the Magnetic Constants as derived (1) *from Sabine's Charts in the 'Phil. Trans.' of the Royal Society* (1845), *and* (2) *from the Admiralty Charts for* 1880, *expressed in British Units, and converted into c.g.s. Units.*

—	1845		1880	
	British	C.G.S.	British	C.G.S.
g_1^0	6·98081	·321871	6·87176	·316843
g_2^0	– ·0275845	–·00127187	·158464	·0073065
g_3^0	– ·523986	–·0241595	– ·58113	–·026795
g_4^0	– ·67352	–·0310546	– ·73195	–·033749
g_5^0	·0513465	·00236748	·27987	·012904
g_6^0	– ·30013	–·0138385	– ·07904	–·0036446
g_1^1	·602567	·0277832	·52644	·024273
g_2^1	–1·065495	–·0491279	–1·11386	–·051358
g_3^1	·678817	·0312989	·91030	·041972
g_4^1	– ·712584	–·0328558	– ·79880	–·036831
g_5^1	– ·784390	–·0361666	– ·61614	–·028409
g_6^1	– ·272348	–·0125575	– ·59068	–·027235
g_2^2	– ·007649	–·0003527	– ·11506	–·0053054
g_3^2	– ·607671	–·0280185	– ·61198	–·0282172
g_4^2	– ·331346	–·0152777	– ·41928	–·019332
g_5^2	– ·661354	–·0304937	– ·58220	–·026844
g_6^2	·300535	·012932	·15864	·0073145
g_3^3	– ·044994	–·0020746	– ·06274	–·0028928
g_4^3	·076635	·0035335	12123	·0055896
g_5^3	– ·023517	–·0010843	– ·011915	–·0005494
g_6^3	·241583	·011139	·37369	·0172301
g_4^4	·002980	·0001374	– ·02346	–·0010818
g_5^4	·02713	·0012508	·00433	·0001996
g_6^4	·064652	0029810	·07682	·0035421
g_5^5	– ·01512	–·0006970	– ·01435	–·0006615
g_6^5	– ·009531	–·0004394	– ·02154	–·0009933
g_6^6	·003132	·0001444	– ·00047	–·0000218
h_1^1	–1·254179	–·0578277	–1·30780	–·0602998
h_2^1	·039069	·0018014	·28051	·0129335
h_3^1	·297611	·0137222	·16224	·0074808
h_4^1	– ·119841	–·0055256	– ·23026	–·010617
h_5^1	·5291705	·0243990	·58114	·026795
h_6^1	– ·144530	–·0066640	– ·06162	–·002841
h_2^2	– ·254829	–·0116484	– ·27960	–·0128917
h_3^2	– ·088692	–·0040894	·00861	·0003968
h_4^2	·214592	·0098944	·11316	·0052175
h_5^2	– ·025210	–·0011624	·06455	·0029737
h_6^2	– ·069335	–·0031969	– ·17877	–·0082428
h_3^3	– ·146981	–·0067770	– ·10697	–·0049321
h_4^3	·084794	·0039097	·09392	·0043306
h_5^3	·009588	·0004421	·02851	·0013145
h_6^3	·123986	·0057167	·11457	·0052826
h_4^4	·021780	·00100425	·02029	·0009355
h_5^4	·01799	·0008295	·02489	·0011477
h_6^4	·060462	·0027878	·03984	·0018370
h_5^5	– ·00864	–·0003984	– ·00414	–·0001908
h_6^5	– ·049244	–·0022705	– ·02920	–·0013465
h_6^6	– ·005664	–·0002612	·00390	·0001799

Comparison of the Values of the Magnetic Constants in British Units as determined (1) *by Gauss,* (2) *by Erman,* (3) *by Adams for* 1842-45, (4) *by Adams for* 1880, *with their yearly rate of increase from* 1845 *to* 1880.

Constants	Gauss	Erman	Adams		Yearly rate of change
			1842–45	1880	
g_1^0	7·0155	6 9417	6·9777	6·8558	− ·00325
g_2^0	− ·1672	+ ·0262	− ·0124	+ ·1624	·00466
g_3^0	− ·1430	− ·4069	− ·5310	− ·6194	−·00236
g_4^0	− ·8249	− ·5937	− ·6309	− ·7207	−·00239
g_1^1	·6746	·6149	·6145	·5358	−·00210
h_1^1	−1·3545	−1·3036	−1·2622	−1·3166	−·00145
g_2^1	−1·0981	− ·9659	−1·0598	−1·1014	−·00111
h_2^1	− ·0457	+ ·0156	+ ·0421	+ ·2818	·00639
g_3^1	·9316	·6477	·7300	·9505	·00588
h_3^1	·3622	·3567	·2631	·1243	−·00370
g_4^1	−1·1563	− ·8330	− ·6904	− ·7507	−·00161
h_4^1	+ ·4858	− ·0693	− ·1081	− ·2252	−·00312
g_2^2	+ ·0037	+ ·0271	− ·0083	− ·1154	−·00286
h_2^2	− ·2956	− ·2741	− ·2547	− ·2792	−·00065
g_3^2	− ·5546	− ·6664	− ·6006	− ·6057	−·00014
h_3^2	− ·1725	− ·1347	− ·0884	+ ·0079	·00257
g_4^2	− ·3470	− ·3382	− ·3376	− ·4226	−·00227
h_4^2	·3226	·2353	·2160	·1169	−·00264
g_3^3	+ ·0106	− ·0276	− ·0450	− ·0627	−·00047
h_3^3	− ·1421	− ·1572	− ·1470	− ·1070	·00107
g_4^3	·1498	·1455	·0764	·1209	·00119
h_4^3	− ·0013	+ ·0654	+ ·0847	+ ·0938	·00024
g_4^4	+ ·0313	+ ·0194	+ ·0030	− ·0234	−·00070
h_4^4	·0241	·0240	·0218	·0203	−·00004

The multiplier for the conversion from British units into c.g.s. units is 0·046108.

It will be seen on examining these tables (1) that g_4^0 and g_6^0 are numerically very much larger than g_2^0, and (2) that the values of g_2^0 from the same equations differ greatly according as g_6^0 is or is not included, the value of g_2^0 being $-·0276$ when g_6^0 is included, and $-·0124$ when g_6^0 is excluded. It also appears from the comparison of the solutions when the equations of condition are included up to 77½° latitude with the solutions above (*i.e.*, stopping at 67½° latitude) that $g_2^0 = -·0126$ in the first case, and $-·0276$ in the second case, and that this arises from the fact that the sum of the absolute terms in the final equation for g_2^0 is $+·08815$ when we stop at latitude 67½°, and $-·07184$ when we proceed to latitude 77½°. Hence a wide variation in the value of g_2^0 is to be expected in the two cases, even when g_6^0 is included in both sets of equations. It also appears from the above tables that those constants in the values of which Gauss and Erman greatly differ are those which have undergone the greatest apparent changes in the interval from 1845 to 1880, and that the values for 1845 now determined for the most part agree more nearly with those of Erman than with those of Gauss.[1]

The values of the magnetic constants have been determined from the

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[1] It should be remembered that before the excellent Admiralty charts of 1880, prepared by Captain Creak, the magnetic charts of the world were based on observations which were insufficient and not distributed widely or regularly enough over the earth's surface to lead us to expect a close agreement between the results of Gauss's theory as derived from the earlier observations as compared with the later more trustworthy observations.

equations for (X) and (Y) and from the equations for (Z) separately as well as from the equations for (X), (Y) and (Z) combined, and their values have been compared. Also their values have been determined in each case (1) by including all the equations up to (e), *i.e.* between latitudes 67½° N. and 67½° S., and (2) by including all the equations up to (c), *i.e.* between latitudes 77½° N. and 77½° S.

The following table gives the comparative values of the magnetic constants in British units, as deduced from different magnetic elements :—

—	1845		1880	
	From X or X and Y	Z	From X or X and Y	Z
g_1^0	7·012	6·952	6·869	6·877
g_2^0	− ·009	− ·089	+ ·159	+ ·179
g_3^0	− ·564	− ·525	− ·578	− ·574
g_4^0	− ·596	− ·846	− ·800	− ·630
g_5^0	+ ·173	− ·115	+ ·245	+ ·329
g_6^0	− ·148	− ·646	− ·056	− ·005
g_1^1	·597	·605	·497	·536
g_2^1	−1·089	−1·052	−1·097	−1·122
g_3^1	·682	·675	·807	·973
g_4^1	− ·704	− ·726	− ·709	− ·873
g_5^1	− ·858	− ·722	− ·620	− ·643
g_6^1	− ·260	− ·299	− ·343	− ·842
g_2^2	·000	− ·013	− ·098	− ·126
g_3^2	− ·596	− ·617	− ·590	− ·628
g_4^2	− ·353	− ·313	− ·413	− ·423
g_5^2	− ·678	− ·647	− ·574	− ·586
g_6^2	·416	·206	·156	·165
g_3^3	− ·037	− ·051	− ·078	− ·051
g_4^3	·093	·064	·126	·117
g_5^3	− ·028	− ·019	− ·032	+ ·005
g_6^3	·221	·259	·242	·483
g_4^4	− ·001	+ ·006	− ·018	− ·028
g_5^4	·023	·030	·029	− ·016
g_6^4	·055	·073	·073	·081
g_5^5	− ·013	− ·017	− ·013	− ·016
g_6^5	− ·011	− ·009	− ·025	− ·019
g_6^6	− ·002	+ ·008	·001	− ·002
h_1^1	−1·287	−1·240	−1·273	−1·321
h_2^1	·043	·035	·229	·309
h_3^1	·285	·299	·190	·152
h_4^1	− ·192	− ·063	− ·284	− ·192
h_5^1	·534	·503	·724	·478
h_6^1	− ·110	− ·168	− ·366	+ ·223
h_2^2	− ·247	− ·260	− ·265	− ·289
h_3^2	− ·095	− ·083	− ·029	− ·035
h_4^2	·176	·245	·133	·100
h_5^2	+ ·068	− ·098	+ ·037	+ ·078
h_6^2	− ·011	− ·120	− ·172	− ·176
h_3^3	− ·150	− ·145	− ·117	− ·099
h_4^3	·077	·091	·092	·096
h_5^3	+ ·029	− ·007	·031	·027
h_6^3	·026	·205	·135	·098
h_4^4	·021	·022	·030	·012
h_5^4	·025	·012	·051	·003
h_6^4	·050	·070	·054	·028
h_5^5	− ·009	− ·008	− ·006	− ·002
h_6^5	− ·041	− ·056	− ·029	− ·029
h_6^6	− ·006	− ·005	+ ·003	+ ·004

Another method of testing the accuracy of the work of determination of the magnetic constants is to substitute their values in the theoretical expressions for X, Y and Z, and to compare the results with the values of X, Y and Z as taken from the charts.

For this purpose we have to form for each parallel of latitude the value of the expression

$$\begin{aligned}\tfrac{1}{2}(a_m+a'_m)&=X_1^0g_1^0+X_3^0g_3^0+X_5^0g_5^0\\&+(X_2^1g_2^1+X_4^1g_4^1+X_6^1g_6^1)\cos\lambda+(X_2^1h_2^1+X_4^1h_4^1+X_6^1h_6^1)\sin\lambda\\&+(X_3^2g_3^2+X_5^2g_5^2)\cos 2\lambda+(X_3^2h_3^2+X_5^2h_5^2)\sin 2\lambda\\&+(X_4^3g_4^3+X_6^3g_6^3)\cos 3\lambda+(X_4^3h_4^3+X_6^3h_6^3)\sin 3\lambda\\&+X_5^4g_5^4\cos 4\lambda+X_6^5g_6^5\cos 5\lambda+X_5^4h_5^4\sin 4\lambda+X_6^5h_6^5\sin 5\lambda\,;\end{aligned}$$

and also the value of the expression

$$\begin{aligned}\tfrac{1}{2}(a_m-a'_m)&=X_2^0g_2^0+X_4^0g_4^0+X_6^0g_6^0\\&+(X_1^1g_1^1+X_3^1g_3^1+X_5^1g_5^1)\cos\lambda+(X_1^1h_1^1+X_3^1h_3^1+X_5^1h_5^1)\sin\lambda\\&+(X_2^2g_2^2+X_4^2g_4^2+X_6^2g_6^2)\cos 2\lambda+(X_2^2h_2^2+X_4^2h_4^2+X_6^2h_6^2)\sin 2\lambda\\&+(X_3^3g_3^3+X_5^3g_5^3)\cos 3\lambda+(X_3^3h_3^3+X_5^3h_5^3)\sin 3\lambda\\&+(X_4^4g_4^4+X_6^4g_6^4)\cos 4\lambda+(X_4^4h_4^4+X_6^4h_6^4)\sin 4\lambda\\&+X_5^5g_5^5\cos 5\lambda+X_6^6g_6^6\cos 6\lambda+X_5^5h_5^5\sin 5\lambda+X_6^6h_6^6\sin 6\lambda\,;\end{aligned}$$

and then to form the sum and difference of these expressions for the values of X in northern or southern latitudes respectively, which may then be directly compared with the charts.

Similar expressions must be formed in the same way for Y and Z for each parallel of latitude, and their sums and differences taken as in the case of X.

When the values of the magnetic constants had been determined, they were substituted in the equations of condition for each belt of latitude, the terms of which when added up gave the theoretical value of the absolute term for that latitude. This calculated value of the absolute term may then be compared with the value of the corresponding absolute term derived from the observation which has been used in the solution of the equations.

The following table gives some of these comparisons between the calculated and observed values of the absolute terms of the equations of condition for the period 1880, in the values of X and Z for g_n^m, for $m=0$ and n odd, and for X, Y and Z for both g_n^m and h_n^m for $m=1$ and n odd.

The observed values are taken from the Admiralty charts, and are the values used in the solution of the equations, and it will be seen by the comparison of the calculated and observed values that a chart drawn to give the results of the calculations would not differ much from the Admiralty charts.

As a further test of the accuracy of the work in such laborious and extensive calculations, it is interesting to compare the values of the Gaussian constants as determined by different investigators from the observations for different epochs.

Comparison between a few of the Calculated and Observed Values of the Absolute Terms of the Equations for Determining g_n^m *and* h_n^m *for the Epoch* 1880.

Mean Latitudes	In the Equations for g_n^0		In the Equations for g_n^1				In the Equations for h_n^1			
	For $m=0$ and n odd X		For $m=1$ and n odd X		For $m=1$ and n odd Y		For $m=1$ and n odd X		For $m=1$ and n odd Y	
	Calculated	Observed	Calculated	Observed	Calculated	Observed	Calculated	Observed	Calculated	Observed
(a) 85° . . .	0·540	—	−1·026	—	1·031	—	·979	—	− ·969	—
(b) 80° . . .	1·075	—	−1·004	—	1·029	—	1·031	—	− ·991	—
(c) 75° . . .	1·600	—	− ·963	—	1·022	—	1·102	—	−1·024	—
(d) 70° . . .	2·114	—	− ·896	—	1·012	—	1·182	—	−1·066	—
(e) 65° . . .	2·615	2·610	− ·794	−·668	·994	·859	1·249	1·421	−1·114	−1·003
(f) 60° . . .	3·091	3·099	− ·657	−·569	·968	·872	1·288	1·410	−1·164	−1·059
(g) 55° . . .	3·585	3·578	− ·485	−·443	·931	·851	1·289	1·331	−1·210	−1·121
(h) 50° . . .	4·058	4·050	− ·283	−·288	·884	·832	1·244	1·236	−1·253	−1·176
(i) 45° . . .	4·526	4·516	− ·069	−·114	·824	·804	1·153	1·123	−1·287	−1·219
(k) 40° . . .	4·985	4·991	·144	·076	·757	·749	1·025	1·001	−1·312	−1·256
(l) 35° . . .	5·432	5·443	·326	·250	·672	·687	·871	·849	−1·329	−1·288
(m) 30° . . .	5·857	5·867	·466	·390	·606	·611	·705	·686	−1·336	−1·302
(n) 25° . . .	6·249	6·250	·547	·486	·531	·527	·542	·533	−1·337	−1·310
(o) 20° . . .	6·598	6·606	·556	·507	·460	·445	·392	·377	−1·332	−1·311
(p) 15° . . .	6·888	6·895	·495	·452	·400	·372	·265	·244	−1·325	−1·311
(q) 10° . . .	7·106	7·101	·369	·342	·353	·313	·161	·141	−1·319	−1·303
(r) 5° . . .	7·241	7·222	·197	·184	·325	·274	·075	·064	−1·314	−1·298
(s) 0° . . .	7·288	7·255	—	—	·315	·255	—	—	−1·312	−1·287
	Z		Z				Z			
(a) 85° . . .	13·110	—	·197	—	—	—	− ·071	—	—	—
(b) 80° . . .	12·974	—	·402	—	—	—	− ·161	—	—	—
(c) 75° . . .	12·752	—	·691	—	—	—	− ·314	—	—	—
(d) 70° . . .	12·448	—	·925	—	—	—	− ·465	—	—	—
(e) 65° . . .	12·067	12·099	1·149	1·332	—	—	− ·690	− ·780	—	—
(f) 60° . . .	11·613	11·615	1·344	1·444	—	—	− ·954	−1·033	—	—
(g) 55° . . .	11·086	11·073	1·499	1·526	—	—	−1·246	−1·288	—	—
(h) 50° . . .	10·486	10·463	1·596	1·605	—	—	−1·542	−1·571	—	—
(i) 45° . . .	9·810	9·804	1·621	1·644	—	—	−1·824	−1·814	—	—
(k) 40° . . .	9·051	9·040	1·568	1·617	—	—	−2·070	−2·048	—	—
(l) 35° . . .	8·205	8·213	1·443	1·530	—	—	−2·273	−2·248	—	—
(m) 30° . . .	7·268	7·294	1·246	1·329	—	—	−2·421	−2·415	—	—
(n) 25° . . .	6·238	6·253	1·009	1·057	—	—	−2·516	−2·540	—	—
(o) 20° . . .	5·117	5·117	·756	·749	—	—	−2·568	−2·630	—	—
(p) 15° . . .	3·918	3·895	·517	·481	—	—	−2·587	−2·623	—	—
(q) 10° . . .	2·652	2·658	·322	·302	—	—	−2·587	−2·618	—	—
(r) 5° . . .	1·338	1·387	·194	·149	—	—	−2·583	−2·610	—	—
(s) 0° . . .	—	—	·149	·098	—	—	−2·580	−2·590	—	—

The following tables give some comparisons. The first of these tables gives the values of the first twenty-four constants (*i.e*, of those to the fourth order) as determined by Gauss for 1830, by Erman and Petersen, by Adams (1) from Sabine's charts for the epoch from 1842–45, and (2) from the Admiralty charts for 1880, and by Neumayer for 1885, as published in Berghaus' 'Physical Atlas.'

Constants	1829 Erman-Petersen	1830 Gauss	1845 Adams	1880 Adams	1885 Neumayer
g_1^0	+·320074	+·323477	·321871	·316843	·315720
g_2^0	+·001210	−·007708	−·001272	·007306	·007906
g_3^0	−·018763	−·006593	−·024159	−·026795	−·024363
g_4^0	−·027377	−·038035	−·031055	−·033749	−·034395
g_1^1	+·028353	+·031106	·027783	·024273	·024814
g_2^1	−·044537	−·050635	−·049128	−·051358	−·049798
g_3^1	+·029863	+·042956	·031299	·041972	·039560
g_4^1	−·038405	−·053291	−·032856	−·036831	−·030597
h_1^1	−·060109	−·062456	−·057828	−·060300	−·060258
h_2^1	+·000720	−·002107	·001801	·012933	·012999
h_3^1	+·016446	+·016700	·013722	·007481	·007383
h_4^1	−·003197	+·022402	−·005526	−·010617	−·011877
g_2^2	+·001249	+·000172	−·000353	−·005305	−·005667
g_3^2	−·030728	−·025575	−·028018	−·028217	−·027857
g_4^2	−·015592	−·016000	−·015278	−·019332	−·019754
h_2^2	−·012637	−·013631	−·011648	−·012892	−·012604
h_3^2	−·006211	−·007955	−·004089	·000397	−·000443
h_4^2	+·010851	+·014876	·009894	·005217	·007147
g_3^3	−·001272	+·000488	−·002075	−·002893	−·003270
g_4^3	+·006708	+·006909	·003533	·005590	·006842
h_3^3	−·007248	−·006552	−·006777	−·004932	−·005492
h_4^3	+·003014	−·000062	·003910	·004331	·005121
g_4^4	+·000895	−·001442	·000137	−·001082	−·000849
h_4^4	+·001109	+·001109	·001004	·000935	·000968

If we had expressed the magnetic potential and the magnetic forces, X, Y and Z in terms of the functions Q_n^m, $Q_{n_1}^m$, &c., instead of in terms of H_n^m, $H_{n_1}^m$, &c., we should have obtained another series of magnetic constants but the two series are related to one another, and the one series may be derived from the other by multiplying each constant in one series by a factor depending on the values of n and m.

Thus let a_n^m and b_n^m be two magnetic constants derived from the function Q_n^m (as defined above), and let α_n and β_n be the corresponding Gaussian magnetic constants as derived from the function H_n^m. Then these magnetic constants a_n^m and b_n^m are connected with α_n and β_n by the relations

$$\frac{\alpha_n}{a_n}=\frac{\beta_n}{b_n}=\frac{Q_n}{H_n}=\frac{1.3.5\cdots(2n-1)}{(n-m)\,!}$$

for a given value of m; and similarly

$$\frac{\alpha_{n_1}}{a_{n_1}}=\frac{\beta_{n_1}}{b_{n_1}}=\frac{Q_{n_1}}{H_{n_1}}=\frac{1.3.5\cdots(2n_1-1)}{(n_1-m)\,!};$$

and in particular

$$\frac{\alpha_{n-2}}{a_{n-2}}=\frac{\beta_{n-2}}{b_{n-2}}=\frac{Q_{n-2}}{H_{n-2}}=\frac{1.3.5\cdots(2n-5)}{(n-m-2)\,!}$$

and

$$\frac{\alpha_{n+2}}{a_{n+2}}=\frac{\beta_{n+2}}{b_{n+2}}=\frac{Q_{n+2}}{H_{n+2}}=\frac{1.3.5\cdots(2n+3)}{(n-m+2)\,!}$$

then we may find the final equations for a_n and b_n from the final equations for α_n and β_n respectively by multiplying the final equations by $\frac{Q_n}{H_n}$, and then substitute the values of α_n and β_n in terms of a_n and b_n respectively.

Hence, in the final equations for α_n and β_n, the coefficient of α_n or of β_n will be multiplied by

$$\left(\frac{Q_n}{H_n}\right)^2 \text{ or } \left(\frac{1.3.5\cdots(2n-1)}{(n-m)\,!}\right)^2$$

in order to find the coefficients of a_n and b_n respectively.

Also the coefficients of α_{n-2} or of β_{n-2} in the same equations will be multiplied by

$$\frac{Q_n.Q_{n-2}}{H_n.H_{n-2}} \text{ or } \frac{1.3.5\cdots(2n-1).1.3.5\cdots(2n-5)}{(n-m)\,!\qquad(n-m-2)\,!}$$

to find the coefficients of a_{n-2} and b_{n-2} respectively. And the coefficients of α_{n+2} and β_{n+2} will be multiplied by

$$\frac{Q_nQ_{n+2}}{H_nH_{n+2}} \text{ or } \frac{1.3.5\cdots(2n-1).1.3.5\cdots(2n+3)}{(n-m)\,!\qquad(n-m+2)\,!}$$

to find the coefficients of a_{n+2} and b_{n+2}.

Or generally the coefficients of α_{n_1} and β_{n_1} in the final equations for α_n and β_n will be multiplied by $\frac{Q_n.\,Q_{n_1}}{H_n.\,H_{n_1}}$ to find the coefficients of a_{n_1} and b_{n_1} in the corresponding final equations.

Hence the constants a_n^m and b_n^m will have to be multiplied by $\frac{Q_n^m}{H_n^m}$, *i.e.* by the factor $\frac{1.3.5\cdots(2n-1)}{(n-m)\,!}$, in order to obtain the corresponding Gaussian constants α_n and β_n.

Again, let A_n, B_n be two magnetic constants connected with α_n and β_n by the relations

$$\frac{\alpha_n}{A_n}=\frac{\beta_n}{B_n}=\frac{\Pi_n}{H_n}=\frac{1.3.5\ \ldots\ (2n-1)}{[(n-m)\,!\ (n+m)\,!]^{\frac{1}{2}}}.$$

Then the values of the magnetic constants A_n, B_n, &c., as determined from the function Π_n, can be converted into the corresponding Gaussian magnetic constants derived by means of the function H_n by multiplying each magnetic constant A_n^m or B_n^m for each value of m by the factor

$$\frac{\Pi_n^m}{H_n^m}=\frac{1.3.5\cdots(2n-1)}{[(n-m)\,!\,(n+m)\,!]^{\frac{1}{2}}}.$$

In his paper in Vol. I., No. 1 of 'Terrestrial Magnetism,' published January, 1896, at the Chicago University Press, Dr. Ad. Schmidt has introduced a symbol R_m^n, which is connected with the symbol Π_n^m employed above by the relation

$$R_m^n=\sqrt{(2n+1)\epsilon}\ \Pi_n^m$$

where $\epsilon=1$ when $m=0$, and $\epsilon=2$ when $m>0$.

Hence $$\frac{R^n_m}{H^m_n}=[1.3.5\cdot\cdot\cdot\cdot(2n-1)]\left[\frac{(2n+1)\epsilon}{(n-m)\,!\,(n+m)\,!}\right]^{\frac{1}{2}}$$

By means of this factor the magnetic constants determined by Professor A. Schmidt for 1885 may be converted into Gaussian magnetic constants, for the sake of comparison with the magnetic constants as determined by Adams for 1880, and by Neumayer and by Fritsche for the epoch 1885.

Comparison of the Values of Gaussian Magnetic Constants to the Sixth Order in Centimetre-gramme-second Units.

—	Adams	Neumayer	Schmidt	Fritsche
	1880	1885	1885	1885
g^0_1	·316843	·315720	·317346	·31635
g^0_2	·0073065	·007906	·007849	·00526
g^0_3	−·026795	−·024363	−·023415	−·02556
g^0_4	−·033749	−·034395	−·034781	−·04014
g^0_5	·012904	—	·013320	·01208
g^0_6	−·003645	—	−·003932	−·01285
g^1_1	·024273	·024814	·023556	·02414
g^1_2	−·051358	−·049798	−·048954	−·04962
g^1_3	·041972	·039560	·037750	·03807
g^1_4	−·036831	−·030597	−·028389	−·03104
g^1_5	−·028409	—	−·040125	−·03028
g^1_6	−·027235	—	−·004089	−·01686
g^2_2	−·005305	−·005667	−·005868	−·00589
g^2_3	−·028217	−·027857	−·027667	−·02667
g^2_4	−·019332	−·019754	−·020192	−·02128
g^2_5	−·026844	—	−·021920	−·01961
g^2_6	·0073145	—	·008082	·00572
g^3_3	−·002893	−·003270	−·003158	−·00368
g^3_4	005590	·006842	·006463	·00601
g^3_5	−·000549	—	−·000780	−·00272
g^3_6	·017230	—	·015668	·01503
g^4_4	−·001082	−·000849	−·001176	−·00063
g^4_5	·000200	—	·000147	·00134
g^4_6	·003542	—	·00118	·00200
g^5_5	−·0006615	—	—	−·00064
g^5_6	−·000993	—	—	−·00032
g^6_6	−·000022	—	—	·00029
h^1_1	−·060300	−·060258	−·059842	−·05914
h^1_2	·0129335	·012999	·012432	·01307
h^1_3	·007481	·007383	·009073	·01005
h^1_4	−·010617	−·011877	−·015772	−·01381
h^1_5	·026795	—	·027312	·03647
h^1_6	−·002841	—	−·017039	−·01796
h^2_2	−·012892	−·012604	−·013342	−·01230
h^2_3	·000397	−·000443	−·000512	·00013
h^2_4	·0052175	·007147	·006691	·00652
h^2_5	·002974	—	·002549	·00227
h^2_6	−·008243	—	−·009699	−·01122
h^3_3	−·004932	−·005492	−·005396	−·00555
h^3_4	·004331	·005121	·004706	·00525
h^3_5	·0013145	—	·001093	−·00049
h^3_6	·005283	—	·006267	·00757
h^4_4	·0009355	·000968	·000555	·00103
h^4_5	·001148	—	·001692	·00132
h^4_6	·001837	—	·001377	·00346
h^5_5	−·000191	—	—	−·00043
h^5_6	−·0013465	—	—	−·00186
h^6_6	·000180	—	—	·00011

The above table gives the values in c.g.s. units of the Gaussian magnetic constants, as determined by Adams for the epoch 1880, and by Neumayer for 1885, by Schmidt for 1885, and by Fritsche for 1885. The last two determinations by Schmidt and by Fritsche were derived from the observations employed by Neumayer, and the values of the Gaussian constants, corresponding to those published by Schmidt in the first number of the journal 'Terrestrial Magnetism,' are obtained by multiplying each magnetic constant by the value of the above factor $\frac{R_m^n}{H_n^m}$ for that constant.

Stream-line Motion of a Viscous Film.

[Ordered by the General Committee to be printed *in extenso.*]

(I.) *Experimental Investigation of the Motion of a Thin Film of Viscous Fluid.*[1] *By* Professor H. S. HELE-SHAW, *LL.D.*

AT the International Congress of Naval Architects at the Imperial Institute in July of last year the author read a paper on the 'Nature of Surface Resistance,' and there showed by means of lantern experiments that the flow of water round solids of various forms could be made visible by injecting air into the flowing water. In response to an invitation from the Institute of Naval Architects to read a second paper on the subject, he endeavoured to investigate the nature of a very well defined border line which existed in all the experiments when air was used, such as by employing water under various conditions, injecting coloured fluid into the flowing mass on the skin of the bodies in the path of flow. In endeavouring to investigate the markedly different condition of flow at the surface, instead of using a thick sheet of water of from three-eighths to half an inch, a thin sheet of water was employed the thickness of which was not greater than that of the abovementioned border line. The result of doing this was to reveal a different state of flow in the water, in which, though the air method now failed, colour bands remained stable and enabled the behaviour of the water to be clearly seen.

The hypothesis had been advanced in the first paper that, while the general body of the water in the thick sheet was moving with sinuous or turbulent motion, the water near the skin (which of course corresponds with that of the thin sheet) was in a state of parallel flow. The author, by means of a formula which Professor Lamb was good enough to furnish him with, found that within reasonable limits of error true stream line flow took place under these conditions, and gave a number of illustrations of this method of obtaining the form of stream lines round bodies of various cross section and in channels of various forms.

(1.) *The Two Lines of Research possible by means of the Method of Thin Sheets.*

It is obvious that there are two lines of research for which this method might be employed. The first of these is the investigation of the properties of fluids by using sheets of different thicknesses and varying

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[1] The reproduction of the experimental results and diagrams which illustrated the reading of this paper are given in *Engineering* and *The Engineer*.

conditions of velocity of flow in questions of such importance as discontinuity of fluid motion and viscosity. The second purpose for which this might be employed was obviously to investigate the nature of stream line forms in many cases in which mathematical investigation was impossible, not merely for the case of flowing water, but in applications to heat and electricity.

It was in experimenting with various liquids with the first mentioned object in view that much better results were obtained than those given with water, and after working out the test case with various fluids (including water) under new and more rigorous conditions, these results, together with certain new experiments, are brought before the Association.

(2.) *Description of Improved Apparatus.*

In the earlier apparatus the main body of water was supplied in a thin sheet by the pressure from the mains, coloured water being introduced from a small reservoir kept under pressure by means of a hand pump. Since exhibiting these experiments in the earlier part of the year at the Royal Society, improvements have been made both in the general mode of applying the fluid to the lantern apparatus, and also in the lantern apparatus itself, thus rendering the appliance suitable for either physical or engineering lecture purposes, as well as for actual experimental work.

The arrangement consists of a lantern and two vessels, one containing clear liquid and the other coloured liquid, connected by two pipes with the lantern-slide. A pipe leads to the reservoir of compressed air, which is attached to a circular cap, with which the vessels of liquid are connected. Taps enable the connection between the lantern-slide and receiving-vessels to be adjusted, the annular pipe with which the air is connected passing down to the bottom of the connecting-vessels, whereas the taps are so arranged that the pressure of air from the reservoir comes upon the surface of the liquid in each vessel. The containing vessels which have been used up to the present are ordinary glass aërated water-bottles, capable of sustaining 200 lb. per square inch. At the head of the pipe on each containing-vessel a separate pressure gauge can be attached, as well as on the reservoir itself, so that the pressures can be adjusted accurately for any particular experiment. If different liquids are required to be used, they can be connected with the circular head, without the necessity of disconnecting the other containing-vessels.

The chief object with which this arrangement was designed, however, was to enable high pressures, such as from 100 lb. to 200 lb. per square inch, to be employed when very thin sheets of liquid are used, a high pressure being necessary under such conditions in order to insure the flow.

With regard to the lantern slide itself, the original apparatus, although effective, was troublesome to make and manipulate, and did not insure absolute uniformity of the thin sheet, or lend itself to rapid changes. The new device merely consists of a small brass block containing two chambers. It has two pipes projecting from it, communicating with the chambers, one pipe being connected with the vessel of clear, and the other with the vessel of coloured, fluid. The small brass block is merely inserted between two plates of glass, together with a third exactly the same thickness as itself. By then making in thin cardboard, paper, lead foil, or other material a border, together with the required obstacle or channel, and clamping the whole together, an effective and simple lantern-slide is obtained.

(3.) *Result of using Liquids other than Water.*

The four liquids other than water which were experimented with were castor oil, glycerine, alcohol, and mercury, of which glycerine is so entirely and surprisingly satisfactory in every respect as to make it undoubtedly the best material which the author had hitherto worked with for obtaining stream-line figures, and the whole results shown at the reading of the present paper were obtained by using glycerine.

Of course after the glycerine has once passed through the lantern slide the coloured portion has mixed up with the clear, and it can only be employed again for colour bands, but at the same time the thickness of the sheet of flow being small, while the velocity with which perfect results can be obtained is low, there is no reason why this material should not be always employed.

Alcohol has such a low viscosity that it can be employed in sheets of remarkable tenuity; but these sheets have naturally the disadvantage of giving colour bands so thin as to be scarcely capable of photographic reproduction, while the volatile nature of this substance makes it not altogether desirable in close proximity to an arc lamp.

Mercury is of course opaque, but its great density compared with its viscosity makes it most valuable in connection with some experiments, and its lines of flow can be traced if it is not quite pure by marks it leaves on the glass. It is, however, troublesome, since it cannot be used in connection with brass taps or with the brass lantern apparatus.

Castor oil also proved troublesome to work with.

(4.) *Measurements made to compare the Flow with Water, Glycerine, and Alcohol in Test Cases, and Explanation of these Results.*

In the test cases above referred to Professor Lamb kindly sought for and obtained an equation for the stream lines round a cylinder in a parallel channel, and the results of the measurements, although warranting the use of water under these conditions, showed that the flow was not in absolute agreement with the lines plotted from the formula. The author then remarked:—'Although the differences are appreciable, they are to some extent of a nature which must be attributed to the great difficulty, in the first place, of making sufficiently accurate mechanical arrangements, and also from the fact that it takes some little time to plot down the results; and that, during this time, it is extremely difficult with the present appliances to keep a *perfectly* steady and uniform pressure both of the colouring bands and the main body of the water, when each comes from a separate source. Beyond this, however, there is no doubt that the stream lines are slightly pushed away from the obstacle at the point of greatest velocity, *i.e.*, abreast the mid-section. This may be due to the slight effect of viscous resistance parallel to two containing glass boundaries.'

In view of the importance of the matter it seemed worth while to attempt a new and more accurate comparison of the experimental results with the flow for a perfect fluid. In the previous case the formula used was only an approximation, though used within limits that should give a very fair accuracy. Now it was not really necessary to use the special formula for a channel at all, since if one of the cases be taken in which exactly mathematical results can be obtained for an infinite fluid —*e.g.*, a cylinder—it is only necessary to form a border for a given value of the stream function, and the test could be made and stream lines suitably plotted within the artificial border. Glycerine is capable of being used at very low velocities, and is absolutely steady in flow—indeed, owing to its viscosity the lantern slide may be actually removed with the pipes disconnected, and after a lapse of even half an hour the stream lines remain perfectly clear and distinct. It therefore seemed possible to make an absolutely severe and final test, and the case of a cylinder and infinite width of fluid were taken, the stream lines being plotted from the well-known formula. This plotting was done by Mr. E. Brown, B.Sc., University and 1851 Exhibition Scholar, who kindly undertook this particular work for the author, besides rendering him valuable assistance with the experiments for the present paper.

On plotting the stream lines on a large scale, it was noticed that at a distance from the cylinder corresponding to the distance at which colour bands had previously been admitted, the stream lines were by no means equally spaced, and moreover they were far from parallel to the direction of flow of the fluid at infinity. To overcome this difficulty the stream lines were extended to such a distance from the cylinder that they became for all practical purposes parallel to the direction of flow at infinity. The thin film slide was lengthened by a corresponding amount. Further, it was noticed that at that distance the lines on the diagram, which represent the theoretical stream lines, have a displacement from the lines which correspond to the equal spacing of the stream lines only actually attained at infinity. The colour bands were therefore admitted to the film by holes which were so spaced as to correspond with the displacement of the theoretical lines.

The following three conditions were therefore introduced into the test experiment, viz.—

1. Theoretical stream line as boundary.
2. Longer film.
3. Unequal spacing of stream lines.

It was then found that the actual colour bands were in *absolute* agreement with the theoretical lines.

It must be remarked that in the previous verifications referred to the author had been content to throw the lantern picture so as to most nearly approximate with the theoretical diagram, which involved an obvious displacement of the section of the cylinder itself, but in the present case no such approximation was allowed in the border; the obstacle in the lantern itself was placed in absolutely exact position, so as to coincide with the border on the plotted diagram. It need scarcely be said that this result was not obtained without much laborious work, and it is highly gratifying to know that the correctness of the result has been verified mathematically in the accompanying paper by Professor Sir G. G. Stokes, the conditions which it there states as necessary—viz., considerable viscosity and very thin sheet—being both found necessary in order to obtain the theoretically correct result. It should be noted that on the large scale in which the comparisons were made by the lantern there is not the slightest difficulty in detecting minute variations, and no hesitation or doubt as to when accurate agreement is obtained.

Both water and alcohol have been tried in a similar test case, although the conditions are much more difficult to comply with in these cases, thin sheets, such as $\frac{1}{1000}$th of an inch, which have to be used, making the experiments much more difficult.

The results of stream-line flow by this method may therefore be received with confidence, and a number of cases of stream lines have been obtained by using glycerine. These experiments were made in the first case with the view of studying discontinuity under conditions which involve a severe test of the stability of the thin film, which was throughout of a thickness of $\frac{1}{200}$th of an inch, and in all cases forty-one colour bands were used within a width of about 3 inches. Without the figures themselves, which, as already mentioned, are published elsewhere, it is impossible to do more than describe the general results; but it may be said that the difference between using square corners and rounded edges is very marked; indeed, it was a matter of surprise to find the flow maintained so well over the sharp edge at all. It is evident that the liquid which actually adheres to the edge of the obstacle enables a definite though very minute rounding to take place at the corners, as is visible by a close examination of the photographs. This was especially marked in one case on one side of an experiment, whereas on the other side, when the entering colour band actually touches the edge, the sharp corner takes effect upon it, and completely breaks it up, destroying the continuity of flow.

It may be said that in these examples the narrow portion of the orifice is so small that it is impossible to detect the separate bands which pass through that portion; these colour bands, nevertheless, emerge quite distinct from each other, and finally assume their original position in the wider portion of the channel. One example may specially be mentioned, viz., that of a flat plate inclined at 45° to the stream. The agreement of this case with the theoretical result of Professor Lamb the author has previously been able to verify in the case of water, but even with the greatest care it was always possible to tell in which direction the stream was flowing. With glycerine, however, the colour bands are practically identical before and behind the plate; and if it were not for the point being clearly evident at which the central divided band reunites, it would be impossible to tell which way the stream is flowing. This point of union of the two portions of the central band is extremely interesting, as a careful measurement of it verifies the exact position at which the central stream line meets the plate, and is found to agree precisely with the mathematical solution of the problem.

(5.) *Method of Investigating Effects of Variable Resistance.*

In order not to prolong the present paper beyond reasonable limits, the author will only briefly mention a method by which variable resistance can be dealt with. If within the thin sheet of flowing liquid an obstacle of some transparent material less in thickness than the sheet itself be placed, the flow will take place partly over the obstacle and partly round it. This effect will correspond to that of an obstacle through which fluid can flow, but which opposes resistance greater than the remaining portion of the thin sheet.

The converse effect can be produced by making a part of the thin sheet rather deeper than the remaining portion. This of course will correspond to the flow through an obstacle of similar shape, which opposes less resistance than the surrounding space. The effects are obviously the same as would be produced in the first case by a dia-magnetic body, and in the second case by a para-magnetic body, and by varying the relative thickness of the different portions of the sheet it is clear that the effects which would be given by the body of any known resistance (*i.e.*, of any value of μ) can be produced.

The author at first attempted to produce these results by very thin sheets of glass. It was seen that where the stream meets the edge an effect corresponding to refraction is produced, but that while in the case of the plate touching at both edges, although the velocity must obviously be greater over the portion where the plate is partly obstructing the channel, that is, makes the channel rather shallower, the width of the colour bands remains the same. When, however, the obstacle does not touch the edges, the effect is to produce very much wider bands over the obstacle itself and narrower bands on either side, these bands giving an indication of the great difference of velocity which results from the greatly increased resistance over the surface of the obstruction.

Instead of considering merely the actual width of the bands, it is of course possible, and generally more convenient, to consider the number of bands in a given space. This method is applied to a circular hole in a plate of different cross sections to the film itself, which is placed across the entire width of the channel, and the number of bands or stream lines in a given space in the hole or well is obviously greater than in the surrounding portion—*i.e.*, the bands are close together, and the velocity correspondingly greater. This result evidently represents the effect of placing in a uniform magnetic field a circular cylinder of soft iron—*i.e.*, a para-magnetic body. This sufficiently indicates the method, but other examples may be given, the first two representing para-magnetic and dia-magnetic cylinders, which are cases which can be dealt with by means of mathematics; also two other cases of cylinders of rectangular section, representing respectively the result with para- and dia-magnetic bodies, which are cases it has been hitherto impossible to deal with by mathematical methods.

(6.) *The Effect of Using a Wedge-shape Section.*

The author attempted to solve the problem of obtaining the flow round a solid of revolution by using a wedge-shaped section, the obstruction being also represented by a wedge representing a segment of the body, the thinnest part of the wedge corresponding to the axis of revolution.

Professor Stokes has been good enough to look into this matter, and has found that the partial differential equation which the stream-line function must satisfy in the case of a slender wedge of viscous fluid is

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}-\frac{3}{y}\,\frac{d\psi}{dy}=0,$$

x being measured parallel and y perpendicular to the edge; whereas, for a perfect fluid flowing axially over a solid of revolution, generated by the revolution round the edge of the wedge of the body interrupting the flow in the wedge of fluid, the equation is

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}-\frac{1}{y}\frac{d\psi}{dy}=0,$$

which is not the same as the other, and therefore the stream lines are not the same in the two cases.[1]

If we compare together the case in three dimensions given by Professor Lamb of the flow of a perfect fluid round a sphere and the case actually obtained by this method with glycerine, it will be noticed, as might have been expected, that the lines round the section of the sphere are crowded much more closer together for physical reasons which are easily explained; for it is obvious that, as the whole of these effects depend upon viscosity, the effect of viscosity diminishes in the thicker portion of the wedge in such a way as to make the general velocity of flow greater, and hence the stream lines round the obstacle are not deflected from their path to the same extent as they would be if they were of uniform flow in a parallel portion of the stream.

One result, however, of great interest was obtained, and that was that with less viscous fluids, such as water, the exact point at which the colour bands broke up could be traced by this method, and the flow studied side by side with stream-line motion.

This leads the author, in conclusion, to bring forward an experiment upon continuity with thick sheets, which it may be interesting to show, as indicating clearly the great difference between the flow according as the motion is sinuous or otherwise, and particularly as throwing some insight into the birth of eddies, at the sharp edges of the body. The obstacle itself is of wedge-shape cross section, the edges of the wedge being ground as sharply as possible. Coloured liquid is now allowed to flow behind the plate by means of a small orifice, and the effect can be immediately seen. As long as the water is flowing steadily, the shape of the curves formed by the clearly marked border between the dead water and the water flowing over the edges of the plate agrees more or less with that given by calculation. When, however, the flow, instead of being steady, takes place in a series of impulses, the exact character of the succession of eddies formed at the sharp edges of the plate is clearly seen.

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[1] Since this paper was read Professor Sir G. G. Stokes has further investigated the matter, and has been able to obtain the equation of the stream lines for the case of a slender wedge of a viscous fluid interrupted by a wedge forming a section of a sphere, which he finds in terms of polar co-ordinates to be as follows:—

$$\left(\frac{a^5}{r}-r^4\right)\sin^4\theta=\text{constant.}$$

The two following equations, therefore, may, for convenience, be expressed thus:

Case of flow of perfect fluid round a sphere:

$$\left(1-\frac{a^3}{r^3}\right)r^2\sin^2\theta=\text{constant.}$$

Case of slender wedge with spherical sector:

$$\left(1-\frac{a^5}{r^5}\right)r^4\sin^4\theta=\text{constant;}$$

and Professor Stokes remarks that the equation shows, even without plotting, the general character of the difference between the wedge lines and spherical lines.

(II.) *Mathematical Proof of the Identity of the Stream Lines obtained by Means of a Viscous Film with those of a Perfect Fluid moving in Two Dimensions.* *By* Sir G. G. Stokes, *F.R.S.*

The beautiful photographs obtained by Professor Hele-Shaw of the stream lines in a liquid flowing between two close parallel walls are of very great interest, because they afford a complete graphical solution, experimentally obtained, of a problem which, from its complexity, baffles the mathematician, except in a few simple cases.

In the experimental arrangement liquid is forced between close parallel plane walls past an obstacle of any form, and the conditions chosen are such that whether from closeness of the walls, or slowness of the motion, or high viscosity of the liquid, or from a combination of these circumstances, the flow is regular, and the effects of inertia disappear, the viscosity dominating everything. I propose to show that under these conditions the stream lines are identical with the theoretical stream lines belonging to the steady motion of a *perfect* (*i.e.*, absolutely inviscid) liquid flowing past an infinitely long rod, a section of which is represented by the obstacle between the parallel walls which confine the viscous liquid.

Take first the case of the steady flow of a viscous liquid between close parallel walls. Refer the fluid to rectangular axes, the origin being taken midway between the confining planes, and the axis of z being perpendicular to the walls. As the effects of inertia are altogether dominated by the viscosity, the terms in the equations of motion which involve products of the components of the velocity and their differential coefficients may be neglected. Gravity, again, need not be introduced, as it is balanced by the variation of hydrostatic pressure due to it. The equations of motion, then, with the usual notation, are simply

$$\frac{dp}{dx} = \mu \left(\frac{d^2u}{dx^2} + \frac{d^2u}{dy^2} + \frac{d^2u}{dz^2}\right),$$

with similar equations for y, v and z, w, μ being the coefficient of viscosity.

In the present case the flow takes place in a direction parallel to the walls, so that $w=0$, and the third equation of motion gives $\frac{dp}{dz} = 0$, so that p is constant along any line perpendicular to the walls. The velocities u, v, vanish at the walls, and along any line perpendicular to the walls are greatest in the middle. As by hypothesis the distance $(2c)$ between the walls is insignificant compared with the lateral dimensions of the obstacle, the rates of variation of u and v when x and y vary may be neglected compared with their variation consequent on that of z. Hence the equations of motion become simply

$$\frac{dp}{dx} = \mu \frac{d^2u}{dz^2}, \quad \frac{dp}{dy} = \mu \frac{d^2v}{dz^2}, \tag{1}$$

which must be combined with

$$\frac{du}{dx} + \frac{dv}{dy} = 0. \tag{2}$$

Over an area in the plane xy, which is small compared with the obstacle, though large compared with c^2, the whole velocity and each component vary, as we know, as c^2-z^2; so that if u^1, v^1 denote the mean components along a line perpendicular to the walls

$$u=\frac{3}{2}u^1\left(1-\frac{z^2}{c^2}\right), v=\frac{3}{2}v^1\left(1-\frac{z^2}{c^2}\right),$$

and (1) and (2) give

$$\frac{dp}{dx}=-\frac{3\mu}{c^2}u^1, \quad \frac{dp}{dy}=-\frac{3\mu}{c^2}v^1, \quad \frac{du^1}{dx}+\frac{dv^1}{dy}=0. \tag{3}$$

If ψ be the stream-line function, taken, say, with reference to the mean velocities u^1, v^1,

$$d\psi=u^1dy-v^1dx,$$

and the elimination of p from the first two equations (3) gives

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}=0. \tag{4}$$

The general partial differential equation (4), combined with the condition that the boundaries shall be stream lines, serves to determine completely the function ψ. It may be remarked that the lines of equal pressure are the orthogonal trajectories of the stream lines, and can therefore be drawn from the photographs. If we suppose the stream lines equally spaced out in a part of the fluid where the flow is uniform in parallel lines, the velocity at any point will be inversely as the distance between consecutive stream lines. This statement is subject to a qualification which will be mentioned presently.

Let us turn now to the other problem, that of determining the stream lines for the irrotational motion in two dimensions of a perfect liquid flowing past an infinitely long body, a transverse section of which, by two close parallel planes, would form the obstacle in our thin plate of highly viscous liquid. In this case the stream line function satisfies the same partial differential equation (4) as before, and the conditions at the boundaries are the same, namely, that the boundaries shall be stream lines. Therefore, notwithstanding the wide difference in the physical conditions, the stream lines are just the same in the two cases. In this latter case they cannot be almost realised experimentally by means of an almost perfect fluid on account of the instability of the motion. The orthogonal trajectories of the stream lines are lines of equal velocity-potential, but not in this case lines of equal pressure.

It may be objected that the stream lines cannot be the same in the two cases, inasmuch as the perfect liquid glides over the surface of the obstacle, whereas in the case of the viscous liquid the motion vanishes at the surface of the obstacle. This is perfectly true, and forms the qualification above referred to; but it does not affect the truth of the proposition, which applies only to the limiting case of a viscid liquid confined between walls which are infinitely close. Any finite thickness of the stratum of liquid will entail a departure from the identity of the stream lines in the two cases, which, however, will be sensible only to a distance from the obstacle comparable with the distance between the walls, and therefore capable of being indefinitely reduced by taking the walls closer and closer together.

Tables of Certain Mathematical Functions.—Report of the Committee, consisting of Lord Kelvin (*Chairman*), Lieut.-Colonel Allan Cunningham (*Secretary*), Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. MacMahon, *and* Professor A. Lodge, *appointed for calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.*

The new 'Canon Arithmeticus' is a set of tables showing the solutions of the congruence of $2^x \equiv R$ (mod. m) for all prime moduli ($m = p$) $<$ 1000, and also for all powers of primes as moduli ($m = p^2, p,^3$ &c.) $<$ 1000. The tables are *twofold*, one showing the value of R to argument x, the other showing the value of x to argument R. The tables are on the same plan as Jacobi's 'Canon Arithmeticus,' differing therefrom only in that the same base 2 is used throughout, whereas Jacobi uses a *primitive root* of each prime as *base*; these primitive roots (*e.g.* 967) are often very inconvenient for purposes of *practical* computing.

The tables are now complete (in MS. 133 foolscap sheets), and ready for printing. All the work has been done by two independent computers: the work of each has been checked with that of the other; all discrepancies found have been examined anew and set right.

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Professor G. Carey Foster (*Chairman*), Mr. R. T. Glazebrook (*Secretary*), Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, *and* Oliver J. Lodge, Lord Rayleigh, Dr. A. Muirhead, Mr. W. H. Preece, Professors J. D. Everett *and* A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald *and* J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Mr. E. H. Griffiths, Professor A. W. Rücker, *and* Professor A. G. Webster.

The work of testing resistance coils has proceeded as usual during the year.

The following is a list of the coils tested and of the values found in continuance of the list published in the Report for 1896 :—

TABLE.

No. of Coil		Resistance of Coil in Ohms	Temperature
Elliott, 333 . . .	℄ No. 459	9·9953	13·4°
Elliott, 322 . . .	℄ No. 460	·099662	13·6°
Elliott, 357 . . .	℄ No. 461	9·9938	13·5°
Elliott, 356 . . .	℄ No. 462	·99921	13·6°
Elliott, 358 . . .	℄ No. 463	100 (1 – ·00051)	13·4°
Nalder, 5329 . . .	℄ No. 464	100 (1 – ·00049)	12·8°
Nalder, 5330 . . .	℄ No. 465	1000 (1 – ·00083)	12·6°
Sci. Inst. Co. . . .	℄ No. 466	1·00032	15.8°
Muirhead, 5271 . . .	℄ No. 467	·99722	15·9°
Elliott, 339 . . .	℄ No. 469	·99994	15·9°
Paul, 39 . . .	℄ No. 470	10·0029	16·6°
Paul, 50 . . .	℄ No. 471	1000 (1·00048)	16·7°
Nalder, 3873 . . .	℄ No. 367	9·9901	13·9°
Nalder, 3874 . . .	℄ No. 362	9·9896	13·9°
		Resistance in B.A. Units	
B.A.U. 7_5	℄ No. 468	1·00021	17·1°

The most interesting of the coils are those numbered ℄ 362, 367, 389, 390. (See Appendix I.)

Of these ℄ 367 and ℄ 362 are two ten-ohm coils of platinum silver and Nos. ℄ 389 and ℄ 390 are two tenth-ohm coils of manganine; the values of these are given in Appendix I. These were made for Professor J. V. Jones' experiments on the value of the standard of resistance, and were compared with the standards of the Association in 1893 and 1894.

It appears from the further comparisons, an account of which is given in the Appendix to this report, that ℄ 367 has changed by possibly three or four parts in one hundred thousand, but that no appreciable variation has occurred in the other coils.

The temperature coefficients of the two ten-ohm coils have recently been determined with great care by Mr. M. Solomon in Professor Ayrton's laboratory. An account of the determination is given in Appendix II.

Another coil of interest is a British Association unit, one of those originally made by Matthiessen in 1862 or 1864, which has been in India since that date. This coil was brought home by Professor R. Ll. Jones. A careful comparison with the standards shows that it is correct at 16·3°. According to the stamp on the coil, it was originally correct at 16·2°.

In consequence of his appointment as Treasurer of the Association, Professor Carey Foster has resigned the position of Chairman of the Committee, which he has held for many years. The Committee in asking for reappointment recommend that Lord Rayleigh be the Chairman.

The standards of the Association have, since the opening of the Cavendish Laboratory, been kept at Cambridge in the custody of the Secretary. Mr. Glazebrook has now left Cambridge for Liverpool, and the Committee at a meeting in London agreed that Mr. Glazebrook be authorised and requested to retain the custody of the standards. In consequence, the various standards will in the course of the autumn be installed in the Laboratory of University College, Liverpool.

At the Toronto Meeting the Committee agreed that it was a matter of urgent importance that the general question of the absolute measurement of electric currents should be investigated, and a grant of 75*l.* was made for the purpose.

During the year Professors Ayrton and J. V. Jones have concluded some preliminary experiments with this object, and have designed a form of current weighing apparatus calculated to give results of great accuracy. Drawings of the apparatus have been laid before the Committee and the details of its working explained to them. The estimated cost of the apparatus is 280*l.*; to meet this the grant of 75*l.* made last year remains in hand.

After careful consideration and discussion the Committee, at their meeting at Bristol, agreed unanimously to the following resolution :—

The Committee, having heard from Professors Ayrton and J. V. Jones an account of their preliminary experiments on the absolute determination of the ampère and their plans for the construction of an absolute ampère balance, are of opinion that, in view of the importance of the proposed experiments, application should be made for leave to retain the unexpended balance, 75*l.*, of the grant made last year, together with a further grant of 225*l.*

Accordingly the Committee ask for reappointment and apply for the above grant. They recommend that Lord Rayleigh be Chairman, and Mr. R. T. Glazebrook Secretary.

APPENDIX I.

Comparison of the Standard Coils used by Professors J. Viriamu Jones and W. E. Ayrton in their determination of the absolute resistance of Mercury with the standards of the Association. By R. T. GLAZEBROOK, *F.R.S.*

These coils consist of two tenth-ohm standards of manganine, and two tenth-ohm standards of platinum silver.

The method employed in comparing the tenth-ohm standard is described in the Report of the Committee for 1894 (Oxford Meeting) 'Report,' p. 128. In certain of the experiments the same mercury cups were used as in 1894; in others, the cups used by Professor J. V. Jones in his absolute measurements were employed. The Standard Coils made use of were the following :—Elliott, No. 269; Elliott, No. 270; and Nalder, 3716, the last being a ten-ohm standard, the others units.

The following values were found :—

Nalder, 4274. 389.

R.T.G.'s	mercury cups used	·100049	14·2
,,	,,	·100051	14·1
,,	,,	·100045	14·3
,,	,,	·100030	13·4
,,	,,	·100054	15·7
,,	,,	·100050	16·1
J.V.J.'s	,,	·100030	13·1
,,	,,	·100042	13·7
R.T.G.'s	,,	·100044	13·7
,,	,,	·100042	14·1
J.V.J.'s	,,	·100043	14·1
Mean		·100044	14·2

Nalder, 4275. 390.

R.T.G.'s	mercury cups used	·100060	14·4
,,	,,	·100061	14·4
,,	,,	·100057	14·5
,,	,,	·100040	13·4
,,	,,	·100063	15·8
,,	,,	·100056	16·1
J.V.J.'s	,,	·100045	13·1
,,	,,	·100052	13·7
R.T.G.'s	,,	·100055	13·7
,,	,,	·100054	14·1
J.V.J.'s	,,	·100055	14·1
Mean		·100054	14·3

The values found in 1894 were respectively

·100050 and ·100053

in each case at 15·2°, and the differences are probably within the errors of observation. If all the individual observations for both 1894 and 1897 be plotted, they will be found to overlap each other, and it is difficult to assert that there has been any change. If any exists it is certainly very small.

FIG. 1. No. 4274.

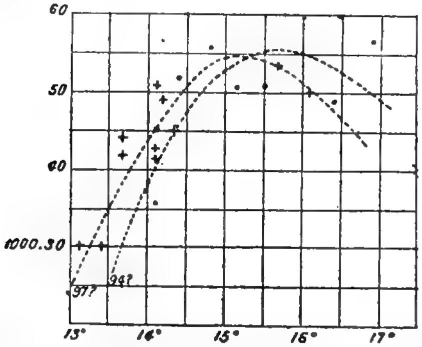
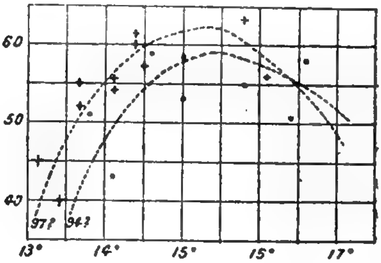


FIG. 2. No. 4275.



Results of observations on the ·1 ohm coils used by Professors Ayrton and J. V. Jones.

Observations in 1894, thus •
Observations in 1897, thus +
The horizontal divisions are 0°·1 C.
The vertical divisions are ·000005 ohm.

This is shown in figs. 1 and 2, in which the observations indicated by dots give the results of the 1894 experiments, those indicated by crosses the experiments of 1897. At a glance the observations do not appear very good, but it must be remembered that the vertical ordinates are drawn to a very large scale, the division being five-millionths of an ohm. For both coils the resistance appears to reach a maximum at about 15·5° C.

The ten-ohm coils were compared in the usual manner on the Carey Foster bridge with the Standard Coil, Nalder, 3716.

The following are the values found :—

Nalder, 3873. 367.

Date	Value	Temperature
December 9, 1897 . .	9·9913	14·3
„ 11 „ . .	9·9917	14·4
„ 13 „ , .	9·9891	13·5
„ 28 „ . .	9·9877	13·15
„ 30 „ . .	9·9909	14·2
Mean.	9·9901	13·9

Nalder, 3874. 362.

Date	Value	Temperature
December 9, 1897 . .	9·9907	14·3
„ 11 „ . .	9·9911	14·3
„ 13 „ . .	9·9886	13·5
„ 28 „ . .	9·9873	13·1
„ 30 „ . .	9·9904	14·05
Mean	9·9896	13·9

The values found in 1893 and 1894 were as follows :—

For 3873, 9·9919 at 14·8°.

If we take the temperature coefficient as ·0028—the value given by Messrs. Nalder—this becomes 9·9894 at 13·9°. Thus the coil appears to have risen in value by ·0007 ohms ;

while for 3874, the value found was 9·9926 at 14·9°.

Messrs. Nalder give the temperature coefficient as ·003, and this leads to the value, 9·9896 at 13·9°, agreeing exactly with the observations of December 1897.

The results of these observation are shown in figs. 3 and 4. The dots refer to the 1893 observations, the crosses to those of 1897. It appears that No. 3874 has not changed ; with regard to No. 3873, a change is indicated. As to this change, it appears from the note-book that there was some doubt as to the temperature of one of the observations in 1893 ; it is recorded as 14° ; the observation shows that the temperature must have been about 13·7°. Furthermore, the value of the ten-ohm standard used for 3873 was not definitely determined in 1893. If allowance is made for these two facts, the value of 3893 at 13°·9 is raised to 9·9923; thus the curve shown in fig. 3* is obtained, and the apparent change in value is reduced to about ·0003 ohms, or three parts in one hundred thousand. On the whole, then, I conclude that 3873 has changed since 1893 by about this amount, while 3874 has remained stationary in value. The discrepancy between this conclusion and that given by Mr. Solomon in Appendix II. depends on the different values employed for the temperature coefficients.

FIG. 3. No. 3873.

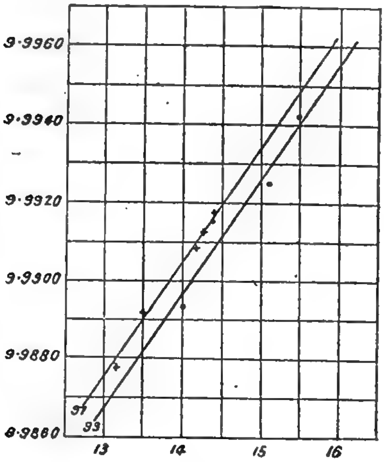
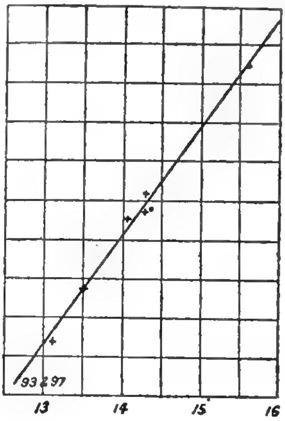


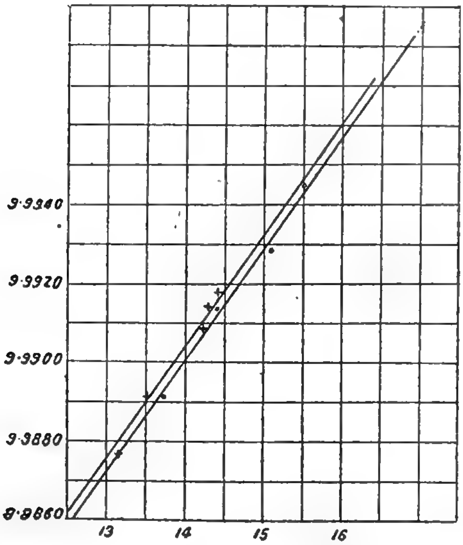
FIG. 4. No. 3874.



Result of observations on the 10-ohm coils, used by Professors Ayrton and J. V. Jones.

Observations of 1893, thus •
Observations of 1897, thus +
The horizontal divisions are 0·1° C.
The vertical divisions are ·0002 ohms.

FIG. 3*. No. 3873. *Revised.*



Observations of 1893, corrected to final value of 10-ohm standard, shown thus •
Observations of 1897, thus +

The values of these coefficients obtained over so short a range are not of much importance. Still, in view of Mr. Solomon's determination, they may be given. They are: For 3873, ·000283; and for 3874, ·000277. These values are relative to the standard coils of the Association.

APPENDIX II.

On the Determination of the Temperature Coefficients of Two 10-*Ohm Standard Resistance Coils* (*Nos.* 3873 *and* 3874) *used in the* 1897 *Determination of the Ohm. By* M. SOLOMON.

In the determination of the ohm made by Professor W. E. Ayrton and Professor J. Viriamu Jones in 1897 (Report, 1897, p. 212), four standard resistance coils were used, two of which had a resistance of 10 ohms each, and two of 0·1 ohm each. Values for the temperature coefficients of these coils had been calculated from four accurate determinations of their resistance made, two by Mr. Glazebrook in 1894 and 1897, and two by the Board of Trade in 1896 and 1897 ('The Electrician,' vol. xl., p. 39). The values thus obtained neither agreed with one another nor with the coefficients given by the makers, Messrs. Nalder Bros. & Co. It therefore became necessary to make as accurate a determination as possible to endeavour to find the correct values for the coefficients. The following Paper gives the results of the tests made on the two 10-ohm coils (Nos. 3873 and 3874), the tests on the other two coils being not yet completed. These two coils are of the B.A. pattern, and are made of platinum silver wire. A preliminary series of tests made on one of the coils showed that to attain the required accuracy special precautions would have to be taken to keep the coils at steady temperatures. Each coil was therefore placed in an oil bath, the temperature of which was automatically regulated. In making the determination of the temperature coefficient of one coil, the other was used as a standard, and was kept at a constant temperature throughout the whole series of tests. The coil under test was maintained at a steady temperature for some time, and a measurement of the difference of resistance between it and the standard was then made by means of a Carey Foster bridge. The temperature of the coil being tested was then altered and a fresh measurement taken, this being repeated for several temperatures.

The apparatus used in the measurements was arranged in the following manner. The standard coil was placed in an oil bath with two vessels, in the inner of which the coil itself and a carefully standardised thermometer were immersed. In the outer bath was the bulb of an alcohol thermometer, the mercury index of which, when the temperature rose too high, completed the circuit of an electromagnet and battery, and caused the gas which heated the bath to be put out. On the bath then cooling the circuit of the electromagnet was broken, and the gas turned on and relighted by a bypass. This thermostat was very sensitive, the temperature of the inner bath rarely varying so much as 0·05° C. in a day, and in a run of ten days undergoing a maximum variation of 0·3° C. The thermostat in which the coil under test was placed was not so sensitive, but was designed to work over a greater range of temperature. The coil and thermometer were placed in an inner bath, and in the outer bath was a large brass bulb filled with alcohol. The expanding alcohol either passed into a small reservoir, or, when the passage to this was closed by shutting a stop-cock, it expanded into one arm of a glass U tube, thereby forcing a mercury index at the bottom up the other arm; this index cut off the gas supply by closing the aperture of the inlet tube. On cooling the index sank; the gas was turned on and relighted by a bypass. Regulation of the temperature accordingly did not take place until the path leading to the reservoir was closed, so that regulation at any desired temperature could be obtained by leaving the stop-cock open until that temperature had been reached. In this case, as also in the other thermostat, the bath was not heated directly by the gas jet, but a baffle plate was interposed. The daily variation of temperature with this apparatus was about 0·2° C., but the changes were so slight and so slow that the probable error introduced would be less than that caused by error in reading the thermometer. The bath was always kept at a constant temperature for some hours before readings were taken. With these arrangements it was safe to assume that the temperature of the coil was the same as that read off from the thermometer. The terminals of the coil dipped into mercury cups in one end of a pair of stout copper rods, half an inch in diameter, the other ends of which rested in mercury cups on a Carey Foster bridge. The leads from each of the coils were of very small and approximately equal resistance, so that no appreciable error could be introduced by alteration in their resistance with change of atmospheric temperature. Also, as a part of each lead was inside the thermostat, heat lost by conduction along the leads would be withdrawn from this part and not from the coil itself.

The measurements were made with a Carey Foster bridge, the platinum silver slide wire of which had been previously calibrated. This wire was 50 centimetres long, and had a resistance of 0·001859 ohms per half centimetre at 13·5° C., and was graduated in half millimetres. Correction was made for alteration in the resistance of the wire due to change in its temperature, an increase of 1° C. producing an increase of 0·000011 ohms in the resistance of half a centimetre. Determinations of the difference of resistance between the two coils were made at intervals of about an hour, and if two or three quite consistent readings could be taken these were considered as correct, but where discrepancies occurred the mean of several results was taken. The slight changes in the temperature of the standard were easily allowed for, since it could be assumed that for such small changes the two coils had the same temperature coefficients. So if the standard, instead of being at the temperature t, were at the temperature $t+\delta$, and if the coil under test were at the temperature t', it was assumed that the standard was at temperature t, and the coil under test at the temperature $t'-\delta$.

There are four principal sources by which error can be introduced—viz., error in obtaining the correct position of balance, error in the value of the temperature coefficient of the slide-wire, error in reading the temperature of the standard coil, and error in reading the temperature of the coil under test. As regards the first of these, the sensibility of the arrangement was such that a change of half a millimetre in the position of the slider produced a deflection of about a centimetre on the galvanometer scale, so that balance could easily be obtained correct to 0·05mm. The error due to not knowing the temperature coefficient of the slide-wire with certainty will not be great, as all the measurements were made at temperatures near to 13·5° C., at which temperature its resistance was known. The greatest error is introduced in reading the thermometers which were graduated in tenths of a degree, each division being about 0·6mm. in length, so that the temperatures could not be read with certainty to less than 0·02° C. If all these errors should be made in one direction in making one determination of difference of resistance, and all in the opposite direction in making a second, there is a possible maximum error of about 3 per cent. in the value of the temperature coefficient calculated from these two determinations. This is, however, highly improbable, and, moreover, makes no allowance for taking the mean of several readings. The error in the temperature coefficient is probably not greater than 1 per cent., if as great.

The following summarises the results of the experiments :—

Ten-Ohm Standard Coil, No. 3873.

A series of tests was made on this coil in the manner above described, lasting from March 22 to April 1, 1898. Determinations were obtained of the difference between the resistance of No. 3873 at six different temperatures, and the resistance of No. 3874 at 16·70° C., with the following results :—

Temperature of No. 3873	Excess resist. in ohms of No. 3873, above No. 3874, at 16·70° C.	Change of resist. per 1° C.
(*a*) 16·31° C.	−0·001896	0·00307
(*b*) 19·33° C.	+0·007380	0·00291
(*c*) 22·10° C.	+0·01545	0·00291
(*d*) 22·43° C.	+0·01639	0·00278
(*e*) 25·43° C.	+0·02470	0·00277
(*f*) 26·22° C.	+0·02678	0·00274

From readings *a*, *b*, *c*, and *e*, and from the measurement of the resistance of the coil made by Mr. Glazebrook in December, 1897, giving $R_{13\cdot9^\circ}=9\cdot9901$ ohms, we get

$$R_t=9\cdot9398\,(1+0\cdot000397t-0\cdot000002(4)t^2).$$

After testing this coil the other coil (No. 3874) was tested, and then three check tests were made on this coil with the following results :—

Temperature of No. 3873	Excess resistance in ohms above No. 3874, at 16·70° C.
(*g*) 19·62° C.	+0·008398
(*h*) 15·95° C.	−0·003074
(*k*) 18·13° C.	+0·003704

These points lie well on the curve obtained in the former tests (see fig. 5). From the formula given above the coil will have the correct resistance of 10 ohms at 17·0° C.

To compare the temperature coefficient here obtained with those previously determined we have four measurements of resistance, as follows:—

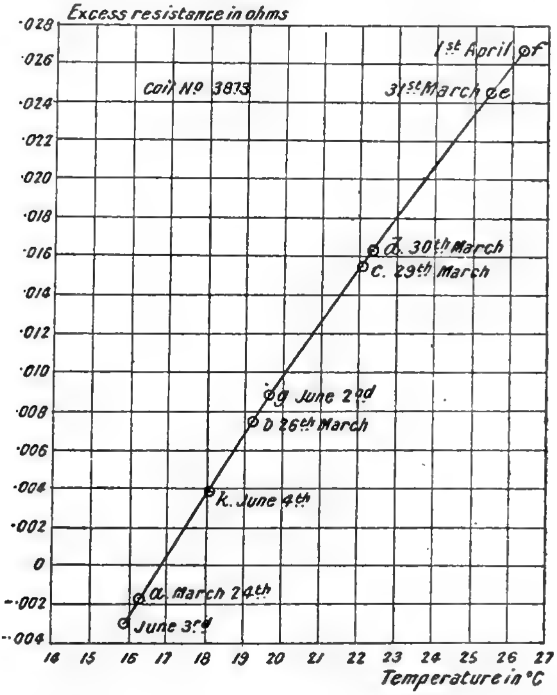
A. Mr. Glazebrook in March, 1894. Resistance = 9·9923 ohms at 14·8° C.
B. Board of Trade in Nov., 1896. " = 9·992994 " 14·86° C.
C. Board of Trade in Aug., 1897. " = 10·00712 " 19·3° C.
D. Mr. Glazebrook in Dec., 1897. " = 9·9901 " 13·9° C.

These furnish data for calculating the temperature coefficient, and we have also the value given by the makers, Messrs. Nalder Bros. & Co. :—

Observer	Range of Temperature	Temperature coefficient per 1° C.	Coefficient from these tests for same range
Messrs. Nalder Bros. & Co.	17·0° – 22·0° C.	0·000276	0·000303
Tests A and C . . .	14·8° – 19·3° C.	0·000331	0·000315
" B and C . . .	14·86° – 19·3° C.	0·000320	0·000315
" D . . .	13·15° – 14·4° C.	0·000299	0·000330
" D and C . . .	13·9° – 19·3° C.	0·000317	0·000317

This table shows that the coefficients calculated from tests B and C and from tests D and C are both in very close agreement with those I obtain for the same range of temperature.

FIG. 5.



Curve showing change of resistance of 10-ohm standard coil, No. 3873, with change of temperature. Ordinates give excess of resistance of 3873 above 3874 at 16·70° C.

Ten-Ohm Standard Coil, No. 3874.

A series of tests on coil No. 3874, lasting from May 19 to May 31, 1898, were made, and in addition we have one result from the tests on coil No. 3873. Altogether we have the following :—

Temperature of No. 3874	Excess resist. in ohms of No. 3874, above No. 3873, at 17·25° C.	Change of resist. per 1° C.
(*a*) 16·70° C.	−0·00095	0·00334
(*b*) 17·46° C.	+0·00159	0·00332
(*c*) 18·08° C.	+0·00363	0·00323
(*d*) 19·09° C.	+0·00689	0·00306
(*e*) 21·37° C.	+0·01382	0·00286
(*f*) 22·22° C.	+0·01641	0·00278
(*g*) 24·46° C.	+0 02264	

From readings *a*, *c*, *e* and *g*, and Mr. Glazebrook's determination of the resistance in December, 1897, which gave $R_{13\cdot9^\circ}=9\cdot9896$ ohms, we get

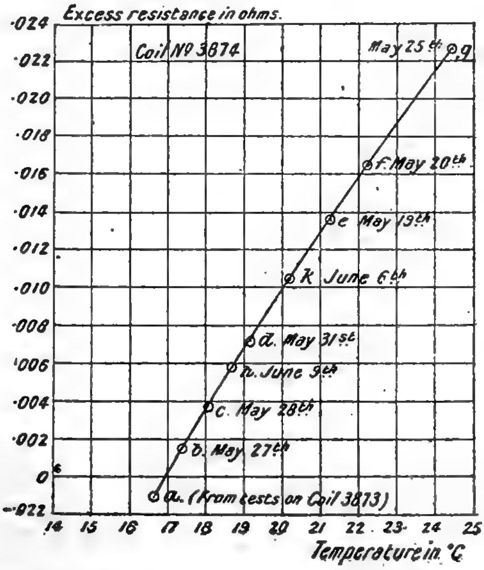
$$R_t=9\cdot9313\,(1+0\cdot000481t-0\cdot000004(2)t^2).$$

Check tests were made on this coil after those on coil No. 3873 had been made, and gave the following results :—

Temperature of No. 3874	Excess resistance in ohms above No. 3,873 at 17·25° C.
(*h*) 18·77° C.	+0·00583
(*k*) 20·15° C.	+0·01040

All the nine points lie on a smooth curve (see fig. 6). These tests make the coil correct at 16·9° C.

FIG. 6.



Curve showing change of resistance of 10-ohm standard coil, No. 3874, with change of temperature. Ordinates give excess of resistance of 3874 above 3873 at 17·25° C.

For purposes of comparison we have a similar set of data to those used for the other coil. The four measurements of resistance gave the following results :—

A. Mr. Glazebrook in March, 1894. Resistance = 9·9926 ohms at 14·9° C.
B. Board of Trade in Nov., 1896. ,, = 9·993213 ,, 14·91° C.
C. Board of Trade in Aug., 1897. ,, = 10·00775 ,, 19·3° C.
D. Mr. Glazebrook in Dec., 1897. ,, = 9·9896 ,, 13·9° C.

From these we get the following values for the temperature coefficient :—

Observer	Range of Temperature	Temp. coeff. per 1° C.	Coeff. from these tests for same range
Messrs. Nalder Bros. & Co.	17·0° – 22·0° C.	0·000300	0·000316
Tests A and C . . .	14·9° – 19·3° C.	0·000346	0·000336
,, B and C . . .	14·91° – 19·3° C.	0·000333	0·000336
,, D . . .	13·1° – 14·3° C.	0·000279	0·000365
,, D and C . . .	13·9° – 19·3° C.	0·000338	0·000341

Here again the same two sets of tests, viz., tests B and C, and tests D and C, give values for the temperature coefficient very nearly equal to those I obtain for the same range of temperatures.

Since for both coils the temperature coefficients that I obtain agree with those calculated from the three last measurements of resistance—namely, the two measurements by the Board of Trade and Mr. Glazebrook's last test—these experiments seem to show that the coils have not changed since 1896, but that the resistances as measured in 1894 were a little lower than those that would now be obtained at the same temperatures.

This conclusion may be better illustrated by calculating what would be the resistances at the temperatures of the various tests, on the assumption that the coefficients I obtain are correct, and that Mr. Glazebrook's last test (in December, 1897) is correct. We then get the following :—

Temperature of test			Resistance as measured in ohms	Resistance as calculated in ohms
Coil No. 3,873	14·8° C.	(A)	9·9923	9·9930
	14·86° C.	(B)	9·9930	9·9931
	19·3° C.	(C)	10·0071	10·0071
	13·9° C.	(D)	9·9901	9·9901
Coil No. 3,874	14·9° C.	(A)	9·9926	9·9932
	14·91° C.	(B)	9·9932	9·9932
	19·3° C.	(C)	10·00775	10·0079
	13·9° C.	(D)	9·9896	9·9896

Thus we see that the 1894 measurements (A) are too low by as much as 7 parts in 100,000 in the case of coil No. 3873, and 6 parts in 100,000 in the case of No. 3874. In the case of the other two measurements the calculated results only differ from the observed results by 1 or 1·5 parts in 100,000.

These experiments were carried out in the laboratory of the Central Technical College, South Kensington, and I am much indebted to Professor Ayrton and Mr. T. Mather for their valuable guidance and advice.

APPENDIX III.

An Ampère Balance. By Professor W. E. Ayrton, *F.R.S., and* Professor J. Viriamu Jones, *F.R.S.*

The Report of the Committee on Electrical Standards for 1897 ended with the following paragraph :—'It thus appears to be a matter of urgent importance that a redetermination of the electrochemical equivalent of silver should be made and that the general question of the absolute measurement of electric currents should be investigated. . . .' This work we were asked by the Committee to carry out, and a grant of 75*l.* was voted in its aid. We were thus led to examine into the methods which had been employed by Lord Rayleigh, Professor Mascart, and others, for determining the absolute value of a current, as well as to consider some other methods which have not, as far as we know, been hitherto used.

After much consideration we decided to adopt a form of apparatus which, while generally resembling the type employed by some previous experimenters, possessed certain important differences, and, before expending any part of the grant of 75*l.*, to construct, without expense to the British Association, the following preliminary Ampère Balance.

On a vertical cylinder about 17 inches high and 6·8 inches in diameter we wound two coils, about 5 inches in height, separated by an axial distance of 5 inches. The coils consisted each of a *single* layer of about 170 convolutions of wire and were wound in opposite directions. From the beam of a balance there was suspended, inside this cylinder, a light bobbin about 4 inches in diameter, on which was wound a coil about 10 inches long consisting of a *single* layer of 360 convolutions, and the whole apparatus was so adjusted that when the beam of the balance was horizontal the inner and outer coils were coaxial and the top and bottom of the inner suspended coil were respectively in the mean planes of the outer stationary coils.

This arrangement was adopted because with coils consisting of only one layer the geometrical dimensions could be accurately determined, and because the shapes of the coils lent themselves to the use of the convenient formula, readily expressible in elliptic integrals, for the force, F, between a uniform cylindrical current sheet and a coaxial helix, viz. :—

$$F=\gamma\gamma_h\,(M_1-M_2)$$

where γ is the current per unit length of the current sheet, γ_h the current in the helix, and M_1 and M_2 the coefficients of mutual induction of the helix and the circular ends of the current sheet.[1]

The value of a particular current of about 0·63 ampère having been determined *absolutely* by means of this apparatus, the rate at which it would deposit silver under specified conditions was ascertained indirectly, by observing its silver value on a Kelvin balance which had been kept screwed down in a fixed position for several years past and which had been calibrated many times during that period by reference to the silver voltameter.

The result of this preliminary investigation showed that the silver value of the *true* ampère was so nearly equal to the reputed value, viz. 1·118 milligramme per second, as to require the use of an apparatus still more

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[1] See *Proceedings of the Royal Society*, vol. 63: 'On the Calculation of the Coefficient of Mutual Induction of a Circle and a Coaxial Helix, and of the Electromagnetic Force between a Coaxial Current and a Uniform Coaxial Circular Cylindrical Current Sheet.' By Professor J. V. Jones.

perfectly constructed, and therefore of a much more expensive character, to enable the error, if any, in this value to be ascertained with accuracy.

We, therefore, started on the design of the instrument, of which we now submit the working drawings, and for the future construction of which we would ask for a grant of 300*l.* including the unexpended grant of 75*l.* voted last year. And we anticipate that this new piece of apparatus may prove worthy of constituting a national Ampère Balance, the counterpoise weight for which will be determined purely by calculation based on the dimensions of the instrument, the number of convolutions of wire in the three coils, and the value of the acceleration of gravity at the place where the instrument may be permanently set up. In this particular it will differ entirely from the 'Board of Trade Ampère Standard Verified 1894,' which has had its counterpoise weight adjusted so that the beam is horizontal when a current passes through the instrument, which will deposit *exactly* 1·118 milligramme of silver per second under specified conditions. In fact, the proposed Ampère Balance and the existing Ampère Standard will differ exactly in the same way as do a Lorenz apparatus and the 'Board of Trade Ohm Standard Verified, 1894.'

We have to express our thanks to Mr. Mather for taking charge of the construction and use of the preliminary apparatus, for checking all the calculations in connection with the determination of the electrochemical equivalent of silver that was made with it, as well as for superintending the making of the working drawings of the new Ampère Balance. We have also to thank Messrs. W. H. Derriman and W. N. Wilson, two of the students of the City and Guilds Central Technical College, for their cordial assistance in carrying out the work.

Electrolysis and Electro-chemistry.—Interim Report of the Committee, consisting of Mr. W. N. SHAW (*Chairman*), Mr. E. H. GRIFFITHS, Rev. T. C. FITZPATRICK, Mr. W. C. D. WHETHAM (*Secretary*), *on the present state of our knowledge in Electrolysis and Electro-chemistry.*

THE grant of 35*l.* made last year has been expended in improving the apparatus for experiments on the electrical properties of solutions. Measurements have been obtained by Mr. Whetham of the electrical conductivity at 0° C. of dilute solutions of potassium chloride, barium chloride, potassium ferricyanide, potassium bichromate, and sulphuric acid. The freezing points of identical solutions have been observed by Mr. E. H. Griffiths. The measurements are sufficient to indicate that important and unexpected results will be obtained. The reduction of the observations is not yet completed, and, in consequence, the account of the experiments is not ready for publication.

The apparatus is now in working order, and it is hoped that measurements may be obtained for other salts. Unfortunately the room in Mr. Griffiths's laboratory where the experiments have been carried out is no longer available, and some considerable expense must be incurred in reconstituting the arrangement in a different situation. To meet this and the additional expenses incidental to the continuance of the observations it is estimated that at least 25*l.* will be required.

The Committee accordingly ask for reappointment, with the addition of the name of Mr. S. Skinner, one of the Demonstrators at the Cavendish Laboratory, and with a grant of 25*l.*

On the Use of Logarithmic Coordinates.

By J. H. Vincent, *D.Sc., A.R.C.Sc.*

[Ordered by the General Committee to be printed *in extenso.*]

PLATES I.–III.

SECT.

Construction of an Impedance Chart

Construction of a Chart for Waves on a Frozen Sea

Another Method of treating the same Non-translatant

Introduction.

1. In discussing experiments upon the passage of gases through porous plates Professor Osborne Reynolds employed a method of plotting curves,[1] in which the logarithms of two variables are used to find the points on a new curve. This new curve Professor Reynolds calls the logarithmic homologue of the one from which it is derived, and pointed out the

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[1] Sir John Herschel used the logarithmic chart in reducing photometric observations. Art. 285, Cape of Good Hope Observations.

following useful property possessed by the homologues. (We may omit the adjective when no ambiguity is likely to arise.)

'If for two curves (1) and (2) $x_2=ax_1$ and $y_2=by_1$, then $x^1_2=x^1_1+\log a$ and $y^1_2=y^1_1+\log b$; or the logarithmic homologues will all be similar curves, but differently placed with regard to the axes, such that the one curve may be brought into coincidence with the other by a shift of which the coordinates are log a and log b.'[1]

It should be noticed that this shift of the homologue is one of pure translation.

The graphic method of homologues was again used by Professor Reynolds in discussing experiments on the flow of water.[2]

2. Mr. Human has since patented the manufacture of sheets of paper ruled logarithmically.[3] A short account of the use of logarithmic coordinates may be found in Greenhill's 'Differential and Integral Calculus,' 1896 edition; directions for the use of the ruled sheets, with a number of easy examples, are supplied by the publishers of the ruled paper, and the valuable aid to computation which this method gives may now be considered well known.

3. The power of readily moving homologues on the logarithmic paper to represent changes in the original equation was greatly facilitated by the invention of scale lines by Mr. Boys.[4] To explain the use and method of construction of scale lines Mr. Boys drew a chart of wave and ripple velocities, which by its wonderful generality was calculated to emphasise the power of the new method of discussing curves by means of their homologues.

Definition and an Example of a 'Translatant.'

4. Let us consider the equation

$$v^2=\frac{g\lambda}{2\pi}+\frac{2\pi\tau}{\lambda\rho},$$

which is the equation that Mr. Boys took to illustrate the method. It is of the form

$$v^2=a\lambda+\frac{b}{\lambda}.$$

Let a, b, v, and λ become a', b', $v\sqrt[4]{\frac{a'b'}{ab}}$ and $\lambda\sqrt[2]{\frac{ab'}{a'b}}$. The equation remains unaltered; thus, if g, τ, and ρ all change, it is possible, by merely shifting the homologue, to represent the new equation. The homologue of this equation possesses the property of translation.

5. It is of great service in any subject to have a definite nomenclature, and a *curve* whose homologue possesses this property with respect to any particular quantity might be called a 'translatant' with respect to that quantity. The term translatant can also be applied without risk of confusion to the *homologue*.

6. *Definition.*—A curve or its homologue is a translatant with respect to any quantity when an arbitrary change in that quantity is equivalent

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[1] *Phil. Trans.*, 1879, Part II., p. 753.

[2] *Ibid.*, 1883, Part III., p. 947.

[3] Published by Beaves and Stephenson, 8 Princes Street, Westminster.

[4] *Nature*, July 18, 1895, p. 272.

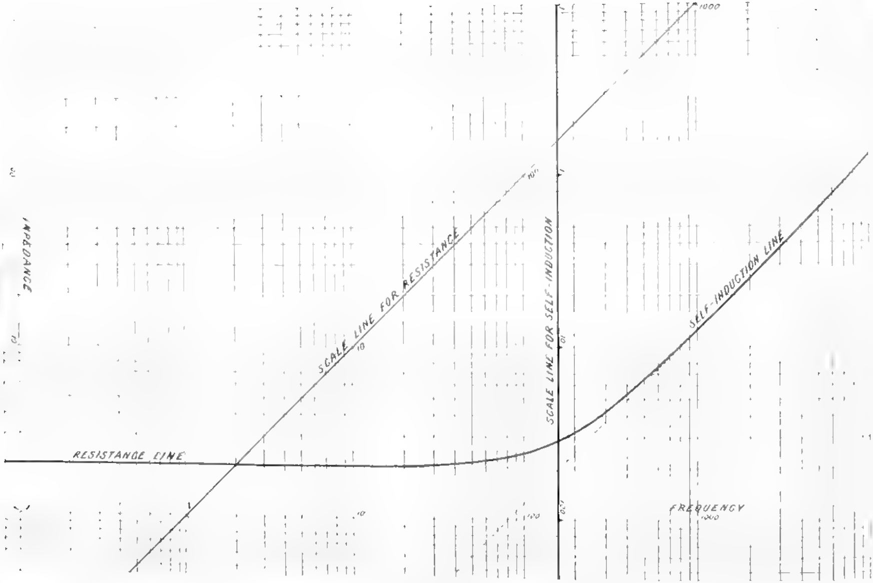

Fig. 1. Impedance Chart

Illustrating Dr. J. H. Vincent's Paper on the Use of Logarithmic Coordinates.

to the transformation $x = ax_1$, $y = by_1$, where a and b are some determinate constants.

Many curves which occur in physics are translatants with respect to all the quantities which are found in the equation; such curves are particularly suitable for treatment by logarithmic coordinates.

CONSTRUCTION OF AN IMPEDANCE CHART.

7. As a second example of a translatant, let us take the equation

$$I^2 = R^2 + 4\pi^2 L^2 n^2;$$

which gives the impedance of a circuit whose resistance is R, self-induction L, and subject to a periodic electro-motive force of frequency n, all expressed in some consistent system of units.

Regarding n as the independent variable, a chart may readily be constructed giving the value of I for any values of R, L, and n; that is, we can in a few minutes produce what amounts to a complete table of the impedance of all circuits subject to a periodic electro-motive force of any frequency.

The equation represents a translatant,[1] for if R and L become R′ and L′ respectively, the equation remains unaltered if n and I be also changed into $\frac{R'L}{RL'}n$ and $\frac{R'}{R}I$. The first step is to draw the homologue for arbitrary values of R and L. Let $R = 2$ and $L = \cdot 002$, these numbers being such as might occur in practice, when L and R are expressed in henrys and ohms.

8. *The Resistance Line.*—If I depended only on the value of R, this would be represented on the chart by a straight line $I = 2$. The line is marked 'Resistance Line' (see fig. 1).

9. *The Self-induction Line.*—If I were a function of L and n only, then the value of I would be given by $I = 2\pi L n$. The homologue of this equation is a straight line, making an angle of 45°, with the increasing direction of the axis of n. To draw it in the proper position of the chart some one point on it must be found; thus, if $n = 100$, $I = 1\cdot 256$. The line is marked 'Self-induction Line' on the chart.

10. *The Complete Impedance Curve.*—The actual impedance is due to both effects, and the curve showing the relation of I to the other quantities concerned runs above the resistance and self-induction lines; it is most distant from either line at their point of intersection, and approaches them asymptotically. The curve very soon, however, becomes practically coincident with the straight lines. The curved portion of the homologue may be drawn by the arithmetical computation of a series of points on the curve; it may, however, be drawn with facility by the following device.

11. *Mechanical Device for Drawing the Curved Portion of the Homologue.*—For any value of n read off on the chart the value of I due to each effect. (In this case the value due to R is constant. It should be noted that when the separate effects are represented by straight lines it is only necessary to read off values through the range n to 10 n, all other values being given at once by appropriately shifting the decimal place.)

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[1] The homologue of any equation of the form $y^l = ax^m \pm bx^n$ is a translatant. For if a, b, x, y^l become $a', b', \sqrt[m-n]{\frac{ab'}{a'b}} \cdot x, \sqrt[m-n]{\frac{a^n b'^m}{a'^n b^m}} \cdot y^l$, the equation is unaltered.

Take a millimetre scale and a sheet of squared paper ruled in millimetres. Mark off OP and OQ at right angles, these lines being taken to represent the magnitude of the two effects. PQ is the length required, being the root of the sum of the squares of the two separate effects.

12. It must next be shown how to adapt the homologue for any values of R and L. This is done by means of scale lines.

A scale line is a line drawn on the chart and graduated by the logarithmic rulings of the paper. It is so placed as to read directly the particular value of the quantity to which it refers, such reading being the indication of the position of the homologue on the paper, and is the magnitude of the quantity in the equation which the homologue represents in its present position.

13. *Scale Line for R.*—If R, n, and I be all multiplied by the same quantity the equation is unaltered; thus when R becomes mR the homologue is to be moved a distance log m to the right, and log m upwards. The direction of translation is along the self-induction line, which could be used as a scale line; in fact any line not parallel to the axis of n could in this case be used as a scale line, the numbers of the graduations being identical with the impedance. In the chart a line at 45° to the axes is drawn and marked 'Scale Line for Resistance.' The direction of motion of the homologue is, in this case, parallel to the scale line.

Scale Line for L.—If L and n vary inversely the value of I is unchanged. If L become mL the homologue must be moved to the left through a distance log m. The scale line must then be parallel to the axis of impedance; when the homologue moves any distance to the left the point of intersection of the self-induction and scale lines will then move upwards by the same amount. To avoid specially graduating the scale line it is drawn through a point on the self-induction line where the impedance reading has the same significant figures as the value of L, for which the self-induction line is drawn. The scale line on the chart is drawn through the point of intersection of $I=2$ with the self-induction line.

14. To find the proper position of the homologue for any value of R and L, move the whole curve with its attendant resistance and self-induction lines by a motion of pure translation until the resistance and self-induction lines cut their respective scale lines at the appropriate readings for R and L.

DISCUSSION OF A NON-TRANSLATANT.

15. Even in the case of some curves which are not translatants the labour of plotting their equations may be greatly reduced by the use of this method. To illustrate this let us take an equation which does not represent a translatant curve.

Professor Greenhill has given the theory of waves on a frozen sea in his article 'Wave Motion in Hydrodynamics.'[1] By retaining a term for the density of the solid in this investigation we have the velocity of propagation and the wave-length connected by the equation

$$u^2=\left(\frac{g\lambda}{2\pi}+\frac{\frac{2}{3}\pi^3e^3\mathrm{E}}{\rho\lambda^3}\right)\Big/\left(\coth\frac{2\pi h}{\lambda}+\frac{s}{\rho}\cdot\frac{2\pi e}{\lambda}\right),$$

---

[1] *American Journal of Mathematics*, vol. ix. No. 1.

where u, λ, g have their usual significance, and

e=thickness of the solid assumed uniform
E=Young's modulus for the solid
ρ=density of the liquid
s=density (not superficial density) of the ice
h=uniform depth of the liquid,

all expressed in some consistent system of units throughout this discussion.

16. *Fundamental Assumption.*—Let us assume that h is large enough compared with $\frac{\lambda}{2\pi}$ for us to write

$$\coth\frac{2\pi h}{\lambda}=1$$

without appreciable error. The equation now becomes

$$u^2=\frac{\frac{g\lambda}{2\pi}+\frac{\frac{2}{3}\pi^3e^3\mathrm{E}}{\rho\lambda^3}}{1+\frac{2\pi es}{\rho\lambda}},$$

which is of the form

$$u^2=\frac{a\lambda+\frac{b}{\lambda^3}}{1+\frac{c}{\lambda}}.$$

This is a non-translatant; if we regard λ and u as the independent and dependent variables, and change a, b, and c into a', b', and c', it is impossible to find two numbers n and m such that the equation

$$n^2u^2=\frac{a'm\lambda+\frac{b'}{m^3\lambda^3}}{1+\frac{c'}{m\lambda}}$$

is identical with the preceding.

CONSTRUCTION OF A CHART FOR WAVES ON A FROZEN SEA.

17. *Short Wave Gravity and Elasticity Lines.*—When λ is sufficiently small for unity to be negligible compared with $\frac{c}{\lambda}$ the equation becomes

$$u^2=a\lambda^2+\frac{\beta}{\lambda^2},$$

where

$$\alpha=\frac{g\rho}{4\pi^2es},$$

and

$$\beta=\frac{\pi^2e^2\mathrm{E}}{3s}.$$

For α, β, λ, and μ write

$$\alpha',\ \beta',\ \lambda\sqrt[4]{\frac{ab'}{a'b}},\ u\sqrt[4]{\frac{a'b'}{ab}}.$$

The equation is unaltered; this shows that it is a translatant. If the first term only in the right-hand member had to be considered, the homologue would be a straight line, making an angle of 45° with the increasing direction of the axis of λ, on the chart; if the second term only were present this also would be represented by a straight line sloping in the opposite direction and to the same extent. To put these lines in the chart it is only necessary to calculate one point on each, and to draw through this point the line in the proper direction.

These lines are drawn on the chart for the case when E[1]$=6\times10^{10}$, $g=981$, $e=100$, $\rho=s=1$. They are marked 'Short Wave Gravity and Elasticity Lines.' (See fig. 2.)

18. *Short Wave Curve.*—To represent the united effect of gravity and elasticity these two lines must be joined by a curve. The whole will then be the homologue of the equation

$$u^2=\alpha\lambda^2+\frac{\beta}{\lambda^2}.$$

The curve is asymptotic to the short wave lines; it very soon becomes practically identical with them. It is symmetrical about a line parallel to the axis of u drawn through the point of intersection of the straight lines; only half need be computed, the other half being put in by geometry. The curve may conveniently be drawn by the method of § 11.

19. It must next be shown how to adapt this curve to any values of α and β. It has been already shown that it is a translatant, and thus the curve will not have to be redrawn, but merely shifted about.

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[1] Most of the experimental investigations into the physics of ice have been concerned with the viscosity and not the elasticity. Professor Greenhill, in the paper already cited, remarks that 'ice was the first substance for which an experimental determination of E was attempted, as described in *Young's Lectures on Natural Philosophy.*' Morgan (*Nature*, May 7, 1885) points out that the value quoted in Thomson and Tait's *Nat. Phil.*, Art. 686, is ten times too great. McConnel (*Proc. Roy. Soc.*, March 1891, p. 343) gives the following values for E:—

92,700	kilos per sq. c.m.	(Moseley), *Phil. Trans.*, 1871
23,632	,,	(Reusch), *Nature*, xxi. 504
60,000	,,	(Bevan)

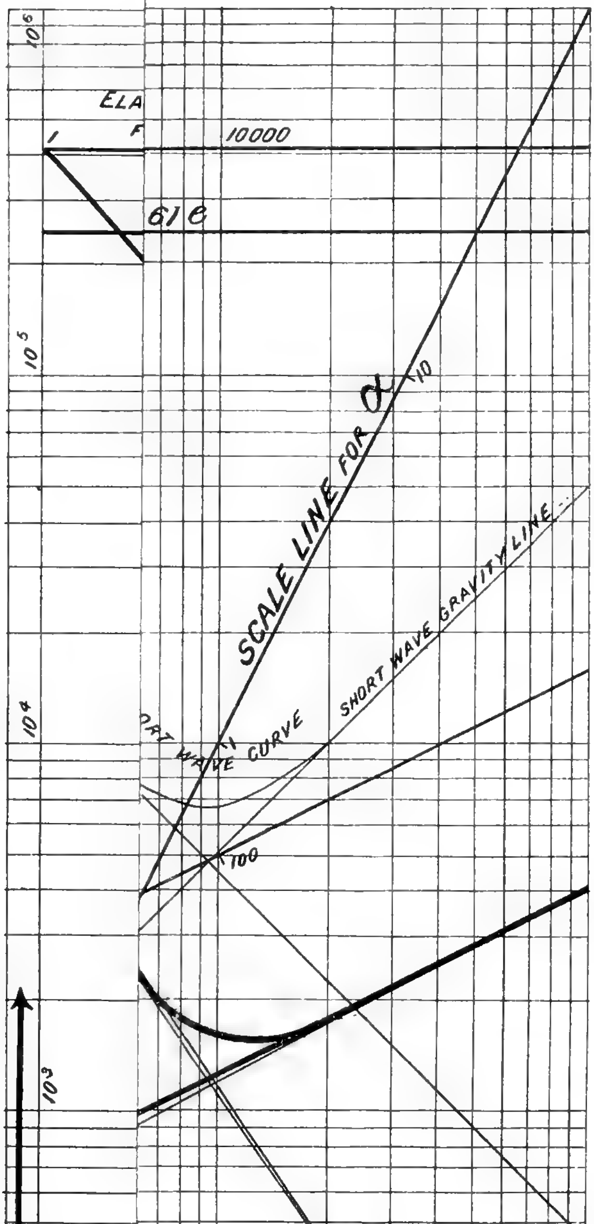
The last value is, presumably, computed from Bevan, *Phil. Trans.*, 1826, Part 3, Paper 21. Turning these values into c.g.s. units we obtain, to the nearest single significant figure—

9×10^{10} (Moseley)
2×10^{10} (Reusch)
6×10^{10} (Bevan)

McConnel considers Moseley's value too great, and implies that Reusch's method was unreliable. By recomputing Bevan's value I obtain 5×10^{10}.

From this it seems that the value of E for ice is somewhere about 6×10^{10} in c.g.s. units; in drawing the first short wave elasticity line on the chart it appeared unnecessary from a physical standpoint to allow for the density of ice and water when the value of E was so uncertain.

Plate 2.


10^6
ELA
F
1
10000
61 e
10^5
SCALE LINE FOR α
10
SHORT WAVE GRAVITY LINE
ORT WAVE CURVE
10^4
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100
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10^2
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10^4
10^12
10^5

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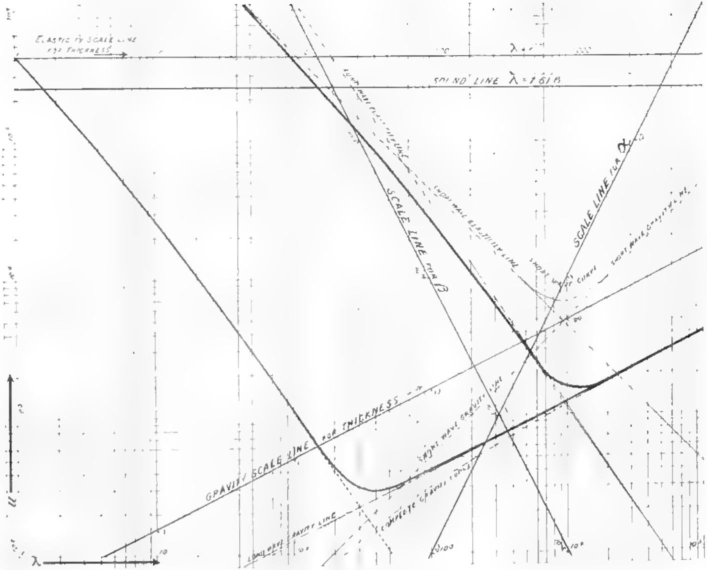


Fig. 2.—Chart of the Velocity of Waves on a Frozen Sea.

Illustrating Dr. J. H. Vincent's Paper on the Use of Logarithmic Coordinates.

20. *The Scale Lines.*—A change in a or β is equivalent to a definite shift of one of the short wave lines, keeping it parallel to itself. This shift might obviously by proper graduations be measured along any line not parallel to the line shifted. By giving the line, along which we wish to measure either of these translations, a proper inclination we can make the lines already on the chart divide this line with the proper logarithmic graduations for a or β, as the case may be.

21. *Scale Line for a.*—This scale line will show how to move the short wave gravity line and the curved portion so as to adapt the chart to new values of gravity, density of liquid and solid, and thickness. The short wave gravity line is the homologue of

$$u^2 = a\lambda^2.$$

If a become na and λ become $\frac{\lambda}{\sqrt{n}}$ the value of u is unchanged. Therefore a shift to the left of $\frac{1}{2}\cdot\log n$ must be made when a becomes $n\,a$; a point on the short wave gravity line must move one large square to the left when the point of intersection on scale moves through two large squares. The scale line will then make an angle $\tan^{-1} 2$ with axis of λ. It must be graduated so that its readings increase as we move upwards on the scale line; the point in which it cuts the short wave gravity line must read the a appropriate to values of g, E, e, s, and ρ in § 17. But the graduation of the u axis must be utilised to save regraduating the scale line. Thus, look for the value of a on the u line; or $10^{\pm n}a$ where n is a whole number; a parallel to axis of λ through this point cuts the short wave gravity line in a point through which the scale line may conveniently be drawn. The graduations are then those of the axis of u multiplied or divided by some positive integral power of 10.

The scale line is inserted on the chart and marked 'Scale Line for a.'

22. *Scale Line for β.*—This scale line shows how to move the short wave elasticity line and the curved portion so as to allow for changes in the values of the density, elasticity, and thickness of the solid. (The short wave elasticity line is not affected by a change in the density of the liquid.) The short wave elasticity line is the homologue of

$$u^2 = \frac{\beta}{\lambda^2}.$$

If β becomes $n\beta$ and λ becomes $\sqrt{n}\,\lambda$, u is unchanged.

A scale line for β is inserted on the chart.

To use the scale lines, move the figure consisting of the two short wave lines and the curve derived from them, without rotation until each of the short wave lines cuts the corresponding scale line in the proper point. The whole operation can easily be accomplished by the use of tracing paper. This translation will obviously move the curve to the correct new position.

23. *Complete Curve obtained from Short Wave Curve.*—There is now on the chart a curve and two scale lines which enable that curve to be shifted so as to represent

$$u^2 = a\lambda^2 + \frac{\beta}{\lambda^2}$$

for any values of g, ρ, e, s, and E. The complete curve to represent

$$u^2 = \frac{a\lambda + \dfrac{b}{\lambda^3}}{1 + \dfrac{c}{\lambda}}$$

must now be drawn. The above equation can be written

$$u^2 = \left\{ a\,\lambda^2 + \frac{\beta}{\lambda^2} \right\} \frac{c}{\lambda + c},$$

where a, β, and c have been previously defined.

When the short wave curve has been placed in its proper position on the chart, calculate c from the equation

$$c = \frac{2\pi e s}{\rho}.$$

From each value of u, as read on the chart, the length

$$\tfrac{1}{2}\,\{\log(\lambda + c) - \log c\}$$

has to be subtracted. The slide rule is an instrument specially designed for the purpose of adding and subtracting logarithms; the operation of drawing the complete curve can be performed by one setting of a slide rule, without other numerical computation. The top scale on Davis's 10-inch slide rule is the same size as the scale of Human's paper; to find a point on the complete homologue set the right hand 1 on the top scale of the sliding piece under the appropriate value of c on the right hand top scale of the rule; the rule as thus set is a table of division of all numbers by c. Add any desired value of λ to c; look for $\lambda + c$ on the top scale and take off distance from the middle '1' of top slide (if $\frac{\lambda + c}{c}$ is less than 10) to $\lambda + c$ on top scale. This length is $\log(\lambda + c) - \log c$. Take off this distance on a pair of proportional compasses set to reduce to one-half. This is the length by which the point on the short wave curve must be dropped to become a point on the complete homologue.

Without resetting the rule repeat the operation with other values of λ.[1] In this way the complete homologue may be drawn without much trouble, and with only so much mental labour as is involved in adding the chosen value of λ to the appropriate value of c.

24. *Recapitulation.*—We have now upon the chart a curve which is the homologue of the complete equation for waves on a solid covering liquid of sufficient depth for coth $\frac{2\pi h}{\lambda}$ to be taken equal to unity. The case where g, E, e, ρ, and s have the values given in sect. 17 is represented on the chart by a thick curved line running beneath the short wave curve. The arithmetical operations necessary to get a curve to represent the

---

[1] If the scale of rule have any size other than that of chart the same method may be used by setting the proportional compasses properly.

The whole operation can be performed without a slide-rule on the chart. Draw a straight line through left hand bottom corner of the paper at an angle $\tan^{-1} 2$ with the horizontal. Use the projection of the left hand coordinates as the one on which to read $\lambda + c$ and c; use the horizontal scale to read off length $\tfrac{1}{2}\{\log(\lambda + c) - \log c\}$.

equation for any values of the quantities involved consist merely in the computation of a, β, and c.

Thus it is possible to obtain by means of logarithmic coordinates a curve giving u for any value of λ without a single operation of the nature of substituting arbitrary values for a variable in the equation.

If it had been merely desired to draw such a curve the task might be regarded as completed; but the equation under discussion may be made to yield many interesting illustrations of the method of homologues. Some of these will now be dealt with.

ANOTHER METHOD OF TREATING THE SAME NON TRANSLATANT.

25. *Long Wave Elasticity Line.*—If the motion were controlled by elasticity alone the equation would be

$$u^2=\frac{\frac{b}{\lambda^3}}{1+\frac{c}{\lambda}},$$

and if λ were so large that $\frac{c}{\lambda}$ could be neglected with respect to unity, the above becomes

$$u^2=\frac{b}{\lambda^3}.$$

The straight line on the chart marked 'Long Wave Elasticity Line' is the homologue of this equation. It makes an angle $\tan^{-1}\frac{3}{2}$ with the decreasing direction of the axis of λ, and in the diagram is placed for the case when e, E, and ρ have the values above quoted.

26.—*Short Wave Elasticity Line.*—This is the homologue of $u^2=\frac{b}{c\lambda^2}$, and is already on the chart, for the case when the quantities concerned have the values already taken.

27.—*Complete Elasticity Curve.*—If the waves were governed by elasticity alone, the homologue showing the value of u for a given value of λ would be coincident with the short wave elasticity line when λ was small, with the long wave elasticity line when λ was great, and would run beneath both lines and leave them to the greatest extent where they cross. To draw the complete elasticity curve we have only to multiply each u by $\sqrt{\frac{c}{\lambda+c}}$, which can be done by one setting of the slide rule as previously shown.

28. *The Two Gravity Lines and Complete Gravity Curve.*— By exactly similar methods the two gravity lines and the complete gravity curve can be inserted on the chart. The long wave gravity line is the homologue of

$$u^2=a\lambda.,$$

The short wave gravity equation is

$$u^2=\frac{a}{c}\lambda^2,$$

and the complete gravity curve is got by mechanical computation, by the same setting of the slide rule as used for the complete elasticity curve, from equation[1]

$$u=\sqrt{\frac{a\lambda^2}{c}}\sqrt{\frac{c}{\lambda+c}}.$$

29. *The Two Complete Curves are Translatants.*—If in the gravity equation

$$u^2=\frac{a\lambda}{1+\frac{c}{\lambda}}.$$

a, c, λ, and u are written a^1, c^1, $\frac{c^1\lambda}{c}$, $u\sqrt{\frac{a^1c^1}{ac}}$, the equation is unaltered. Therefore it is a translatant with respect to a and c.

Similarly the elasticity equation

$$u^2=\frac{\frac{b}{\lambda^3}}{1+\frac{c}{\lambda}}$$

is a translatant.

Subsequently it will be shown how to shift the elasticity and gravity curves to allow for changes in e, E, g, ρ, and s; but in whatever position the two curves may be on the chart the complete homologue of the equation in which both effects appear is found by the method explained in § 11.

30. *Translation of the Elasticity Curve.*—I. New values for e. In the elasticity equation it is seen that if e becomes ne and λ, $n\lambda$: u remains unaltered. Thus to find new position of elasticity curve move it to the right through a distance log n.

II. New values for E. If E becomes nE and u becomes $u\sqrt{n}$ equation is unaltered. Thus to shift the elasticity curve move it through $\frac{1}{2}$ log n upwards.

III. New values for s. When s becomes ns, λ becomes $n\lambda$ and u becomes $un^{-\frac{3}{2}}$, the equation being unaltered. Thus to adapt to new values of s move curve log n to right, and $\frac{3}{2}$ log u downwards.

---

[1] It is perhaps worth noting that the complete elasticity curve could have been computed from

$$u^2=\frac{b}{\lambda^3}\cdot\frac{\lambda}{\lambda+c}$$

and the long wave elasticity line. Also the complete gravity curve could have been obtained from

$$u^2=a\lambda.\frac{\lambda}{\lambda+c}$$

and the long wave gravity line. But in the fraction $\frac{\lambda}{\lambda+c}$ both numerator and denominator change, and a separate setting of the slide rule would be necessary for every new point found on the complete curve.

IV. New values for ρ. If ρ changes to $n\rho$ then u and λ must become nu and $\frac{\lambda}{n}$.

31. *Translation of the Gravity Curve.*—New values for e. If e, λ, and u are changed to ne, $n\lambda$, and $\sqrt{un}$ the gravity equation is unaltered. Thus if e becomes ne move the complete gravity curve log n to the right and $\frac{1}{2}$ log n upwards.

It is unnecessary to show that similar translations may be found for changes in g, ρ, and s.

32. *Scales Lines for Complete Gravity and Elasticity Curves.*—Two scale lines would be needed for each curve to permit of complete generality. Thus the gravity curve would have scale lines for changes in g and in $\frac{se}{\rho}$; the elasticity curve, scale lines for $\frac{e^3E}{\rho}$ and $\frac{se}{\rho}$. These scale lines would all be put in on the same principles as those in the former part of this paper.

33. *Scale Lines for Thickness.*—Two scale lines are inserted on the chart marked 'Elasticity Scale Line for Thickness' and 'Gravity Scale Line for Thickness.' The first of these lines will be understood at once from paragraph 30, I.

From paragraph 31 the direction of motion of the gravity curve in order to adapt it to new values of e must make an angle $\tan^{-1}\frac{1}{2}$ with the increasing direction of the ordinate of λ. Any line drawn on the chart in this direction can be made use of as a scale line. It is convenient, however, to have the scale line placed in a position so that it cuts the complete gravity curve or its attendant short and long wave gravity lines on the chart. The scale line has been drawn at the appropriate inclination through a point on the short wave gravity line where $\lambda=10000$. Now the thickness of ice is here 100; if the scale line be marked 100 at this point it must be graduated in either direction, so that when the curve (and its attendant lines) is moved along the direction of the scale line, the point of intersection of the short wave gravity line and the scale line shall read the thickness on the latter. The scale line must be graduated by a logarithmic scale, so that the readings increase ten-fold for every large square moved through to the right: this is done at once by the graduations on the paper without making a special logarithmic scale.

The complete curve for the case when the values of g, ρ, s, E are the same as before and $e=1$ is inserted on the chart. It cuts the elasticity scale line for e at graduation 1.

If it were only desired to make the chart give at once all values for u and λ when one other quantity such as e was varied the second method of treating the original equation would be the better; but it would become somewhat confusing to use a succession of scale lines in order to adapt the chart to changes in a number of the quantities concerned. If more than one of these has to be altered it would be more convenient to employ the former method.

It must be noted that the complete curve is calculated from the position of the gravity and elasticity curves by the method of § 11. A small portion only joining the two branches has to be drawn, as the complete curve soon becomes indistinguishable from the two component curves.

On Several Outstanding Matters in Connection with the Chart.

34. The long wave lines of the chart may be joined by a curved portion to represent the complete long wave curve, which is the homologue of

$$u^2=a\lambda+\frac{b}{\lambda^3}.$$

This may be obtained by using the method of the root of the sum of two squares; or it may be got by one setting of the slide rule from the short wave gravity curve, this latter curve being the homologue of

$$u^2=\frac{a}{c}\lambda^2+\frac{b}{c\lambda^2}$$

$$=\left(a\lambda+\frac{b}{\lambda^3}\right)\frac{\lambda}{c}.$$

In this case the λ being read directly from the chart no thought is necessary in the operation, the lengths being simply transferred by the proportional compasses. On the chart when ρ, s, ρ, E have the quoted values and $\epsilon=100$ the complete homologue to the original equation is practically coincident with the long wave curve in the curved portion of the latter.

35. It is interesting to compare one of the homologues of the original equation with the wave and ripple curve of Mr. Boys. In the latter on the left we have the capillary ripples where the curve is straight, then the curved portion as far as the point of minimum velocity represents ripples, in the propagation of which gravity has an increasing influence: this is followed by a curved portion in which the surface tension effect is waning, and the gravity influence waxing; finally we have the straight portion which represents waves in which the influence of capillarity is negligible.

The shape of the curve on the chart varies as the quantities g, e, E, ρ, and s alter, as has already been seen. The elasticity and gravity branches always become coincident with the short wave elasticity and long wave gravity branches as we pass to the left and right respectively through a sufficient range.

Consider now the complete curve on the chart representing approximately the facts when the solid is ice and the liquid water and $e=1$. Waves whose length is less than about 420 correspond to ripples; when the wave length falls below about 80 we have the analogues of capillary ripples.

36. The value of λ for which u is a minimum is a solution of the equation

$$\lambda^5+2c\lambda^4-\frac{3b}{a}\lambda-\frac{2bc}{a}=o$$

obtained by differentiating the original equation and putting $\frac{du}{d\lambda}=o$. The ordinary practical way of solving this equation (by numerical computation) is by Horner's method. It has only one real root which is approximately 419 with $e=1$. This root is at once given approximately by the chart, and also the minimum value of u is obtained at once by inspection without the trouble of substituting $\lambda=419$ in the original equation. Logarithmic coordinates may be of use to find the roots of equations of high orders.

37. *The Homologues of Equations representing the Relation of u to λ when $\frac{e}{\lambda}$=some constant.*—In the original equation let $\frac{e}{\lambda}=1$. The equation becomes

$$u^2=\frac{\frac{g\lambda}{2\pi}+\frac{\frac{2}{3}\pi^3\mathrm{E}}{\rho}}{1+\frac{2\pi s}{\rho}}.$$

For all values of λ included in the chart $\frac{g\lambda}{2\pi}$ may be neglected with respect to $\frac{\frac{2}{3}\pi^3\mathrm{E}}{\rho}$; the homologue is a straight line identical with the elasticity scale line for thickness (if we take E, ρ, s as before). In the same way horizontal lines drawn through the points of intersection of lines $\lambda=2$, $\lambda=3$, &c. with the elasticity curve for ice 1 unit thick give the velocity of propagation of waves on ice which is always $\frac{\lambda}{2}$, $\frac{\lambda}{3}$, &c. thick. The size of the waves makes no difference so long as we confine ourselves within the *maximum* range of λ on the chart. This process cannot, however, be continued indefinitely; even when e becomes $\frac{\lambda}{6}$ the line becomes slightly bent upwards as λ approaches 10^5; when $e=\frac{\lambda}{3000}$ or less the relation is expressed by the long wave gravity line already on the chart.

A horizontal line $v=245000$ gives the velocity of propagation of waves when $e=\lambda/1{\cdot}61$; no matter what E may be, the velocity of waves whose length is 1·61 times the thickness of the ice (when $\rho=s=1$) is equal to the velocity of propagation of sound in the ice. The line is marked 'Sound Line' on the chart.

THE USE OF LOGARITHMIC COORDINATES TO FIND AN APPROXIMATE EQUATION CONNECTING A SERIES OF EXPERIMENTAL RESULTS.

38. In practical science this arithmetical problem often arises. If the numbers are merely to be recorded graphically it is always better to plot them logarithmically, as the sensitiveness of the record is independent of the distance of a point from the origin.

If the law which governs the numbers is a straight line law, as is often the case, of course ordinary section paper should be employed. But if on plotting the curve on squared paper it seems to follow some other law, recourse should be had to logarithmic plotting. If the observer commences by trying to find an equation of the form

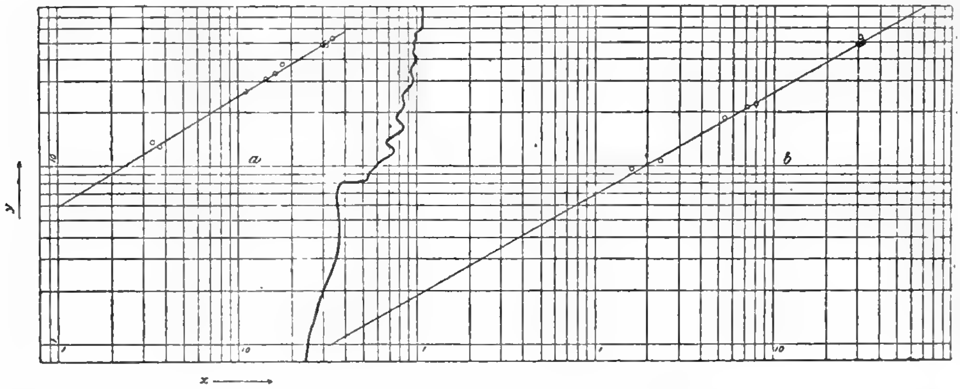
$$y=ax^k$$

by arithmetic he will probably restrict his trial to simple values of a and k. By the use of logarithmic paper he avoids the trouble of looking up the logarithms (as Herschel had to do) and gains in accuracy.

As an example we will find equations connecting two series of experimental numbers (kindly furnished by Mr. Bruce Wade, of Trinity College, Cambridge).

In fig. 3 these two curves are plotted logarithmically. They are each represented very nearly by straight lines, and the equations may be obtained from the figure at once, the power of y being a tangent and the coefficient of x a reciprocal of an intercept.

FIG. 3.



$$(a)\ y^{1\cdot63}=18x.$$
$$(b)\ y^{1\cdot74}=29x.$$

When the equation connecting the values is of the form

$$y^p=ax^q\pm bx^r\pm\&c.$$

the same method could be employed.

TRI-DIMENSIONAL LOGARITHMIC COORDINATES.

39. The construction of a surface to represent the mutual algebraic relationships of three variables is in general a matter of great labour, involving the computation of a series of curves which have then to be placed at appropriate distances apart, and the surface constructed so as to pass through all the curves. Many equations in physics lend themselves very readily to discussion by means of tri-dimensional logarithmic coordinates. Writing down a few which occur, we have

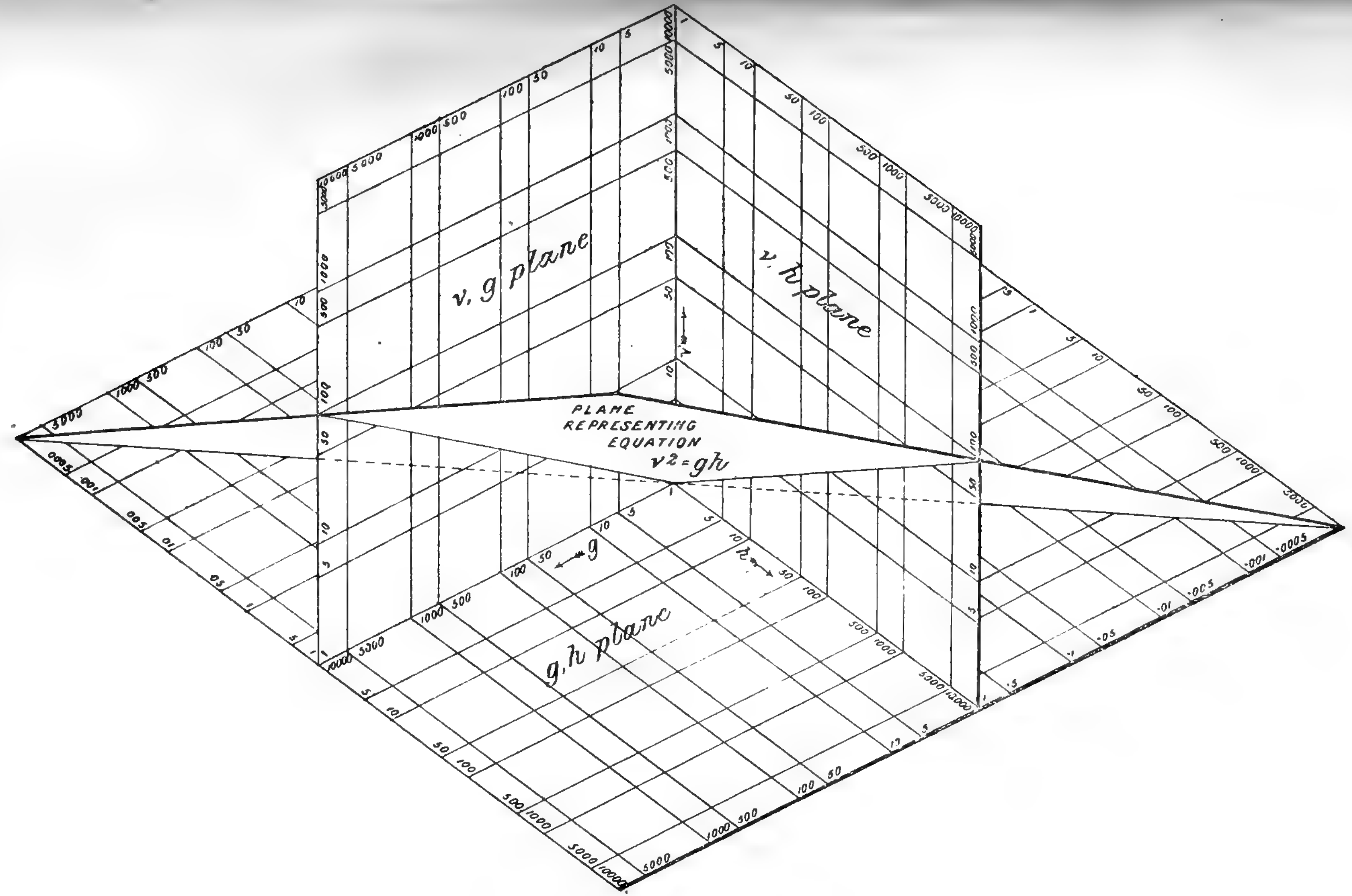
$$pv=\mathrm{R}\theta,\ c=\frac{\mathrm{E}}{\mathrm{R}},\ \mathrm{Q}=c\nu,\ \tau=2\pi\sqrt{\frac{e}{g}}.$$

As one of the simplest of such equations we may take $v^2=gh$, which is the equation of seismic ocean waves.

Regarding v, g, h all as variables, the surface representing the equation in logarithmic coordinates is drawn in fig. 4. This figure is a trimetric projection of a model of the logarithmically ruled planes and the homologue of the surface $v^2=gh$.

It is obvious that scale lines could be used to represent changes in the quantities occurring in equations involving more variables.

FIG. 4.



Model of the Homologue of Surface $v^2=gh$.

SEMI-LOGARITHMIC COORDINATES.

40. For some purposes it would be an advantage to plot the logarithm of one variable against the real value of the other. For instance, suppose it were desired to find the logarithmic decrement of an amplitude which we were investigating. This could be done by setting out the logarithms of swings against the number of the vibration. If the logarithmic decrement did not vary the curve would be a straight line, and the logarithmic decrement would be proportional to the tangent of the angle which this line makes with the decreasing direction of the axis of the number of the swing. If, however, the logarithmic decrement varied with the time, the tangent to the curve at any point would give the logarithmic decrement at that instant. This example is only one of many which suggest themselves; the usefulness of the method in practical work would chiefly depend on the fact that it is easier to 'smooth out' a series of points which should be in a straight line than it would be to draw a logarithmic curve with an elastic rod, as would have to be done if the results were plotted on ordinary square paper.

THE GRAPHICAL COMPUTATION OF THE HYPERBOLIC FUNCTIONS.

41. By the use of semi-logarithmic coordinates it is easy to construct a chart which shall give the values of the six usually used hyperbolic functions for a given value of the independent variable. I have drawn a diagram of this sort which has an accuracy of about one in two hundred, and hope to be able to publish one on a larger scale which shall have a greater accuracy.

For the sake of clearness let the logarithmic scale be regarded as the vertical one and the scale of equal parts as horizontal; further, let the component logarithmic scales in the vertical scale be equal to a unit of length on the horizontal scale.

42. *The Meaning of a Straight Line on the Chart.*—If a straight line be drawn arbitrarily on such a chart (see fig. 5) it gives a series of values for u and f such that—

$$f=10^{mu}c=k^{u}c,$$

where f is the reading on the logarithmic scale and u that on the horizontal scale; c is the reading on the logarithmic scale of the point of intersection of the line with the vertical line $u=o$; k is the tangent of the angle which the line makes with the increasing direction of the axis of u.

Thus any curve having an exponential equation of the form

$$f=ck^{u}$$

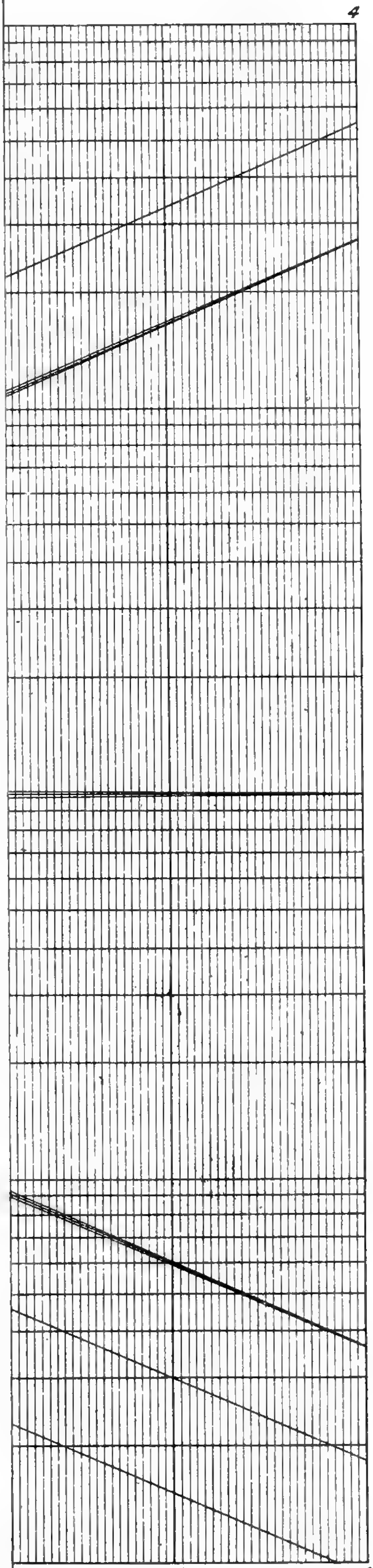
is traced at once by drawing a straight line on the semi-logarithmic chart. No numerical computation is necessary; the value of c is marked on the vertical scale when $u=o$; if k be then marked on the vertical line through $u=1$, a line joining this last point to the point $f=1$, $u=o$ (which may be called the origin) gives us the graph of

$$f=k^{u}.$$

A line parallel to this through the first marked point gives the graph of

$$f=ck^{u}.$$

Plate 3.



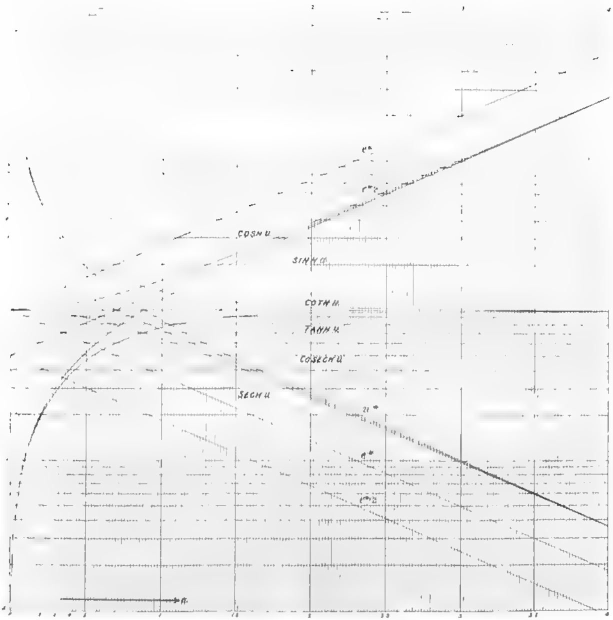


FIG. 5.—Semi-Logarithmic Chart of the Hyperbolic Functions.

Illustrating Dr. J. H. Vincent's Paper on the Use of Logarithmic Coordinates.

A line through the origin and the point $f=10$, $u=1$, gives

$$f=10^u,$$

and this line (which is at 45° to axis of u, since $\log 10=1$ by hypothesis) is a table of common logarithms; the readings of the u scale are the logarithms of the readings of the f scale.

For a line representing

$$f=k^u$$

the u is in any case the logarithmic of f to the base k, so that the semi-logarithmic chart constitutes an infinite series of logarithmic tables to any base.

43. To draw a line representing e^u. This line passes through the origin and the point $f=e$, $u=1$. The e^u line is a table of natural logarithms, u being the natural logarithmic of f.

The accuracy with which such graphic tabulation may be performed is limited by the size and accuracy of the graduations. The size of the u graduations is a matter of choice, as semi-logarithmic charts have to be made and cannot be bought. The logarithmic scales are only obtainable in one size on the ruled paper, but other logarithmic scales can be obtained from slide rules.

Semi-logarithmic charts are free from the defect of ordinary squared paper (as regards the proportionate accuracy of plotting) in the vertical direction. The percentage accuracy of the horizontal scale varies as the distance from zero of the abscissa.

44. To proceed to compute the hyperbolic functions other straight lines must be ruled on the chart. These are inserted without computation. The line representing

$$f=\frac{e^u}{2}$$

is parallel to the e^u line, and is drawn through the point $f=\cdot 5$, $u=0$. The reflexions of these lines in the line $f=1$ give us the e^{-u} and $2e^{-u}$ lines, while a line drawn through $f=\cdot 5$, $u=0$, parallel to the last two, gives us $f=\frac{e^{-u}}{2}$.

45. *The Semi-logarithmic Graph of Sinh u.*—Any point on this curve is found by reading off the values of $\frac{e^u}{2}$ and $\frac{e^{-u}}{2}$ from the appropriate lines for a chosen value of u. Subtract the latter from the former numerically and mark the result on the vertical scale through u. In this way the curve can be readily drawn.

46. *The Cosh u Curve.*—This is conveniently drawn at the same time as the sinh u curve, the values being added. Both curves are asymptotic to the $\frac{e^u}{2}$ line.

47. *The Graphs of Cosech u and Sech u.*—These functions being the reciprocals of those just traced, we have only to make the diagram symmetrical about the line $f=1$ to obtain the two new curves. They are asymptotic to the line $2e^{-u}$.

48. *The Graphs of Tanh u and Coth u.*—These are drawn in from the sinh u and cosh u curves; the vertical distances between these curves

when set out above $f=1$ give the coth u curve, and when set out below, the tanh u curve.[1]

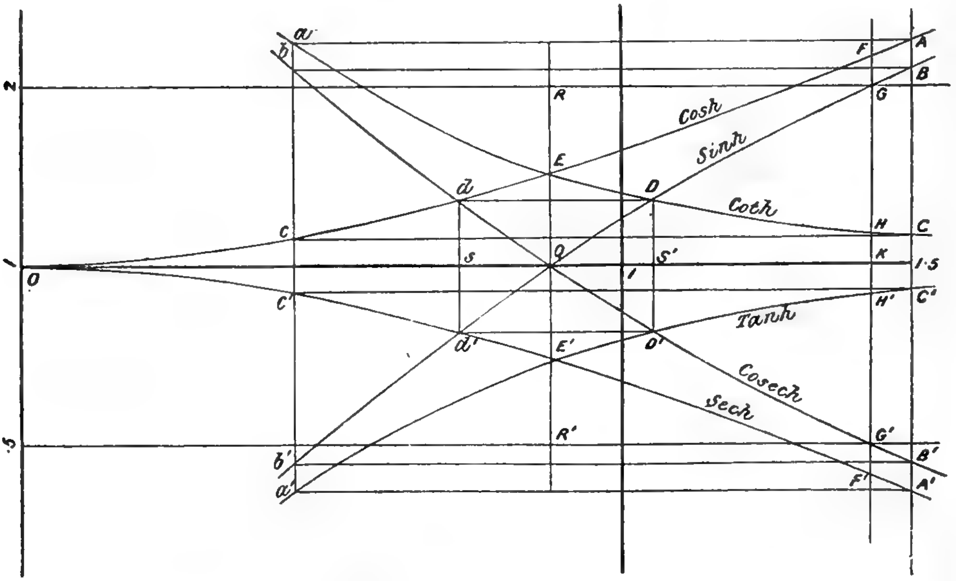
49. A figure constructed thus forms a check on more elaborate numerical computation. It should be noticed that it can be drawn almost entirely by graphical methods, the only numerical value required being the number e.

It is obvious that the semi-logarithmic chart provides a short and easy method of calculating the coordinates of catenaries of which cosh u (on squared paper) is one.

On some Points in the Geometry of the Semi-logarithmic Graphs of the Hyperbolic Functions.

50. If we write down the other hyperbolic functions of u when sinh $u=a$ we find that the values of the six functions are identical with those of u', where u' is defined by sinh $u'=\frac{1}{a}$. The six equations thus obtained may be expressed by saying that any function of a is equal to that function of a' which stands opposite to it in the table—

FIG. 6.



sinh	cosech
cosh	coth
tanh	sech.

Thus (see fig. 6) if a straight line such as AA′ be drawn perpendicular to the axis of u and C be the intersection of this line with any of the six curves (in the figure with coth u); then if a straight line be drawn parallel to the axis of u to cut the curve indicated in above table at the point c (in this case cosh u) a vertical straight line through c will cut all

[1] When u is small, put tanh $u=u$ and coth $u=\frac{1}{u}$.

the curves in values for f which are equal, each to each, to the intersections on the first straight line.

Thus on the diagram the figure Aa' is a rectangle whose sides AA$'$, aa' are bisected by the axis of u, and the lines aA, bB, cC, a'A$'$, b'B$'$, c'C$'$ are all equal and parallel.

This property would be of great value in the origination or verification of tables of these functions.

If D be the intersection of the sinh and coth curves, it follows that DD$'d'd$ is a rectangle whose sides are parallel and perpendicular to the axis of u.

If Q be the intersection of sinh u and cosech u, Q must lie on the axis of u. It follows at once that EQE$'$ is a straight line perpendicular to the axis of u.

51. For the point E we have

$$e^u - e^{-u} = 2,$$

whence

$$e^u = 1 + \sqrt{2},$$
$$e^{-u} = \sqrt{2} - 1.$$

Thus when u has the value given by

$$Mu = \log_{10}(1 + \sqrt{2})$$

($u = {\cdot}88$ approximately),

$$\sinh u = \operatorname{cosech} u = 1$$
$$\cosh u = \coth u = \sqrt{2}$$
$$\operatorname{sech} u = \tanh u = \frac{\sqrt{2}}{2}.$$

The lines $u = 2$ and $u = \frac{1}{2}$ are inserted in fig. 6. RR$'$ is divided into four equal parts by E, Q, E$'$.

52. The value of u which makes cosh u = cosech u is given by

$$\sinh 2u = 2,$$

whence

$$e^{2u} = \sqrt{5} + 2,$$
$$e^{-2u} = \sqrt{5} - 2.$$

The value of u is given by

$$2Mu = \log_{10}(\sqrt{5} + 2),$$

and is approximately 0·72.

The value of cosh u is given by

$$2\cosh^2 u = \cosh 2u + 1$$
$$= \sqrt{5} + 1.$$

Thus

$$\operatorname{cosech} u = \cosh u = \sqrt{\frac{\sqrt{5}+1}{2}}$$

$$\sinh u = \operatorname{sech} u = \sqrt{\frac{\sqrt{5}-1}{2}}$$

$$\tanh u = \frac{\sqrt{5}-1}{2}$$

$$\coth u = \frac{\sqrt{5}+1}{2}.$$

53 When

$$\sinh u = 2$$
$$Os = sK$$
$$\text{and } \cosh u = \sqrt{5}$$
$$\operatorname{cosech} u = \tfrac{1}{2}$$
$$\operatorname{sech} u = \frac{1}{\sqrt{5}}$$
$$\tanh u = \frac{2}{\sqrt{5}}$$
$$\text{and } \coth u = \frac{\sqrt{5}}{2}$$

Sinh $u' = \frac{1}{2}$ has the same values for the functions according to the table in § 50.

On the figure we have

$$\mathrm{FK} = \sqrt{5}, \text{ i.e., the vertical reading at F is } \sqrt{5}.$$
$$\mathrm{GK} = 2$$
$$\mathrm{HK} = \frac{\sqrt{5}}{2}.$$

The lines FG, HK, KH′, G′F′ are equal.

54. To find u when $\sinh u = \coth u$, we have

$$u = \sinh^{-1} u$$
$$= \log_e (\sinh u + \sqrt{\sinh^2 u + 1})\,;$$

whence

$$\mathrm{M}u = \log_{10} \left\{ \frac{\sqrt{5}+1}{2} + \sqrt{\quad \frac{\sqrt{5}+1}{2} \quad} \right\}$$
$$u = 1{\cdot}06 \text{ approximately.}$$

CONCLUSION.

55. It may be noticed that just as some equations are more suited to plotting by means of semi-logarithmic coordinates than by logarithmic coordinates, so advantage may be gained by having only one, or two, of the axes in three dimensions graduated logarithmically.

The more frequent use of logarithmic geometry would tend to simplify many theoretical investigations, and, apart from theory, the aid which the method gives in computation seemed to be sufficient justification for the publication of this paper.

In conclusion I wish to thank Professor J. J. Thomson for several valuable suggestions.

Cavendish Laboratory, Cambridge.

Seismological Investigations.—Third Report of the Committee, consisting of Mr. G. J. SYMONS (*Chairman*), Dr. C. DAVISON *and* Mr. JOHN MILNE (*Secretaries*), Lord KELVIN, Professor W. G. ADAMS, Professor T. G. BONNEY, Dr. J. T. BOTTOMLEY, Mr. C. V. BOYS, Sir F. J. BRAMWELL, Mr. M. WALTON BROWN, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Mr. G. F. DEACON, Dr. G. M. DAWSON, Professor J. A. EWING, Professor C. G. KNOTT, Professor G. A. LEBOUR, Professor R. MELDOLA, Professor J. PERRY, Professor J. H. POYNTING, Dr. ISAAC ROBERTS, *and* Professor H. H. TURNER. *Drawn up by Secretary,* JOHN MILNE.

CONTENTS.

I. *Progress made towards the Establishment of Earthquake-observing Stations in various Parts of the World.*

IN the report for 1897 there will be found a copy of a circular inviting co-operation in the establishment of a seismic survey of the world, which, with the kind assistance of the Foreign, Colonial, and India Offices, was forwarded to many countries and colonies. The result of these communications, together with private correspondence, has been to establish or arrange for the establishment of instruments at twenty-two stations.

The following notes indicate the position we hold in regard to these stations, and the direction in which further co-operation may be expected.

The instruments at Shide, in the Isle of Wight, are indicated as Nos. 1 and 2, but it is only No. 1 that is of the type recommended by this committee. No. 2 consists of a pair of horizontal pendulums writing on smoked paper. Both were purchased by Government grants from the Royal Society.

1. *Canada: Toronto. Meteorological Observatory.*
Professor R. F. STUPART, *Director.*

The instrument (No. 3) reached this station during the meeting of the British Association in August, 1897, when arrangements were made for its installation in a small building outside the Magnetic Observatory. It has already yielded several good seismograms, the most important being that of a West Indian earthquake on December 29. This and other disturbances were also recorded in the Isle of Wight, and are described in this report. Much trouble was occasioned by the frequency and magnitude of 'tremor' storms, especially on frosty nights. Although the marked character of these was reduced by copious ventilation, Professor Stupart writes me that with the hope of getting rid of them altogether he intends to move the instrument inside the main building of the observatory.

This instrument was provided by the Meteorological Observatory, Toronto.

2. *U.S.A.: Cambridge, Mass. Harvard University.*—Professor E. C. PICKERING.

This instrument (No. 4) was shipped from London in September, 1897. On April 13, 1898, Professor Pickering wrote that the instrument, which was purchased by the Harvard University, is to be shipped to their observatory in Peru.

3. *India: Madras. Nungumbaukum. The Astronomical Observatory.*
Dr. MICHIE SMITH.

This instrument (No. 5), after being tested in the Isle of Wight, was delivered at the India Stores in October, 1897. It is now in Madras. It was provided by the Indian Government.

4. *Spain: Cadiz. San Fernando. Instituto y Observatorio de Marina.*
Captain J. VINIÈGRA.

For this instrument (No. 6) the thanks of our committee are due to Mr. R. K. Gray, at whose expense it was constructed. It was shipped in December, 1897, and Captain Viniègra has sent a sample of its records, together with a plan of the observatory, showing the position in which it is installed.

5. *U.S.A.: Philadelphia, Penn. Strathmore College.*
Professor S. J. CUNNINGHAM.

This instrument (No. 7) was constructed at the expense of Mr. Joseph Wharton, 206 Philadelphia Bank Building, Philadelphia, and presented by him to the above institution.

It was shipped from here in November, 1897.

Mr. Wharton very kindly offers further co-operation in the work of this committee.

Professor Cunningham has written describing the installation.

6. *Japan: Tokio. Imperial University.*—Dr. F. ŌMORI.

In a despatch, dated November 22, 1897, Her Majesty's Minister, Sir Ernest Satow, has the honour to inform Lord Salisbury that he communicated with the Japanese Government respecting our circular to which a reply was received from Baron Nishi to the effect that the authorities concerned have decided to co-operate with the British Association.

The instrument (No. 8) was shipped in February, 1897.

7. *England: Surrey. Richmond, Kew Observatory.*—Dr. CHARLES CHREE, *F.R.S.*

The instrument (No. 9) was delivered on March 8, 1898. It was purchased by the Kew Committee, and is now in operation.

8. *Canada: British Columbia, Victoria.*—E. BAYNES REED.

The instrument (No. 10) was sent on March 21, 1898, to the care of Professor Stupart, who will see to its installation. It was paid for by means of the British Association grant given in Toronto, 1897.

9. *Java: Batavia. Magnetisch en Meteorolgisch Observatorium.*
J. P. VAN DER STOK, *Director.*

This instrument (No. 11) was shipped May 1, 1897. It was purchased by the Dutch Government.

10. *Africa: Cape Town. The Observatory.*—D. GILL, *F.R.S., Director.*

On March 19, 1897, Dr. Gill placed our circular before the Admiralty recommending that co-operation be granted. He also pointed out to the Lords Commissioners of the Admiralty that the British Association Committee undertook the labour and cost of discussing results. The instrument (No. 21) was purchased by Her Majesty's Government.

11. *South America: Argentina. Cordova. The Observatory.*
W. G. DAVIS, *Director.*

In November last, after showing Mr. Davis seismograms, he visited Mr. Munro's workshop, where he ordered an instrument. This instrument (No. 14) was shipped from London on May 13, 1898.

12. *India: Bombay. Colaba. The Magnetic and Meteorological Observatory.*
N. A. F. MOOS, *Director.*

The orders for instruments to be established at Bombay and Calcutta originated through a letter of recommendation from the Government of India, Department of Revenue and Agriculture, dated October 7, 1897, addressed to Her Majesty's Secretary of State for India.

13. *India: Calcutta. Alipore. Meteorological Observatory.*
(See Note relating to the Bombay Instrument.)

These instruments (Nos. 12 and 13), which were purchased by the Indian Government, were delivered at the India Stores on April 27, 1898.

14. *Mauritius: Royal Alfred Observatory.*—T. F. CLAXTON, *Director.*

On April 29, 1897, Mr. Claxton wrote that if our committee were prepared to grant 25*l.* towards an instrument he might spare 25*l.* from the Government Grant for 1898. Mr. Claxton's offer was accepted, and the instrument (No. 17) was despatched in July, 1898.

15. *New Zealand: Wellington.*—Sir JAMES HECTOR, *F.R.S.*

Sir James Hector referred our circular to the New Zealand Government, who agreed to ask Parliament for the necessary grant to purchase instruments. On July 30, 1897, Sir James ordered two instruments (Nos. 16 and 20). The former of these was despatched in June, and the latter was despatched on August 31, 1898.

16. *Egypt: Cairo. Abbasich. The Observatory.*

Mr. W. J. Wilson, Inspector-General of Irrigation for Upper Egypt, forwarded to the Ministry of Public Instruction our circular, with the result that H.E. Yacoub Artin Pasha, Under-Secretary of State for Public Instruction, directed that an instrument should be supplied to the above observatory. This (No. 22) will be despatched in September, 1898.

17. *Scotland, Paisley. The Coats Observatory.*

The Rev. Andrew Henderson, Chairman of the Coats Observatory Committee, kindly brought our circular to the notice of that body, with the result that an instrument (No. 18) was ordered on February 21, 1898. It was sent to Paisley in July.

18. *Mexico.*

On May 25 C. Romero, Esq., Acting Chargé d'Affaires at the Mexican Legation, 87 Cromwell Road, London, wrote the Chairman of our committee that he was carrying out instructions received from the Minister of Encouragement (Fomento) of the Mexican Government to purchase a horizontal pendulum. This instrument (No. 19) was despatched on August 15.

19. *Syria: Beyrout. Protestant College.*—Professor R. H. WEST, *Director.*

On the recommendation of Professor R. H. West an instrument (No. 15) was ordered for the observatory at the above college. It was despatched in June, 1898. Professor West says that all records will be at our disposal.

20. *U.S.A.: Washington, D.C. Coast and Geodetic Survey.*
W. W. DUFFIELD, *Superintendent.*

Mr. Duffield wrote on July 16, 1897, that to take up the work proposed would need special authorisation and consequent provision of means. He would send copies of our circular to the United States Naval Observatory, Dr. J. G. Porter, Director of the Cincinnati Observatory, and to the Director of the Lick Observatory.

21. *U.S.A.: Washington, D.C. U.S. Naval Observatory.*
Professor WM. HARKNESS.

On July 19, 1897, Professor Harkness wrote saying that he hoped in the not distant future conditions may present themselves enabling him to co-operate.

22. *S.A.: Colombia, Bogota.*

A despatch, dated August 12, 1897, from Montagu Villiers, Esq., British Vice-Consul at Bogota, to the Marquis of Salisbury stated that the Director of the National Observatory at Bogota hoped before long to purchase the necessary instrument and co-operate in the work of our committee.

23. *Australia: Sydney. The Observatory.*—H. C. Russell, *F.R.S., Director.*

Mr. Russell regretted that, owing to want of funds, he was unable to take a share in the work. He will let us know whether his own pendulum is of any use.

24. *China: Shanghai. Zikawei Observatory.*—L. Froc, *S.J.*

On April 5, 1897, Father Froc wrote regretting that he had neither the means nor the facility to establish an instrument at Zikawei, at which place, he states, the most severe shocks originating in Japan are not experienced.

25. *Malta: Gozo. The College.*—Rev. James Scoles, *S.J.*

Father Scoles, writing from Beaumont College, Old Windsor, said: 'No doubt some interesting results would be obtained in Malta, but in the College there no one has sufficient leisure to attend to such a work, nor are there any funds available.'

26. *Spain: Cadiz.*—W. G. Forster.

Mr. Forster would like an instrument were he at a more favourably placed station, but not where he is.

27. *Brazil: Rio de Janeiro. The Observatory.*—The Director.

On April 20, 1897, the Director of this observatory wrote that he had received through Her Majesty's Minister, Sir Edmund Constantine Henry, the circular issued by this committee. Last June a similar proposal had been received from Dr. Gerland, of Strassburg, to which he had replied favourably. Because nothing further had been heard from Dr. Gerland, the observatory at Rio was prepared to undertake the observations we proposed. The letter concludes with instructions respecting payment for the instrument.

On Jan. 20, 1898, the Foreign Office forwarded to me the translation of a note which Her Majesty's Minister at Rio de Janeiro had received from the Brazilian Government, from which it appears that they are not disposed to co-operate in the scientific observations indicated by this committee.

28. *Hawaii: Honolulu.*—W. J. Kenny, *Her Majesty's Acting Commissioner and Consul-General.*

Shortly after the death of Commissioner Hawes, Mr. T. R. Walker, Acting British Consul-General, placed our circular before Professor W. D. Alexander, who wrote on July 16, 1897, that the proposed station would have to be established in connection with the Hawaiian weather service or at Oahu College, but at present he did not think that the necessary funds were available. The subject should be taken into consideration by the next legislature.

On December 27 Commissioner W. J. Kenny wrote suggesting that seismological investigations be taken up in Hawaii, and if I could send a seismograph he would see to its installation and working.

29. *Physikalisches Central Observatorium.*—Admiral RYKATCHEFF. *Wass.-Ostr., 23 Linci Haus No.* 2, 12/24, *February*, 1898. *St. Petersburg.*

The Russian Meteorological Office think of establishing two instruments of the type recommended by the Seismological Committee of the British Association. It would, however, be first necessary to obtain the opinion of the directors of observatories where the instruments might be installed. Copies of instructions respecting the working of the instruments were required.

Three copies of instructions were forwarded to St. Petersburg on March 3, 1898.

30. *Kaiserliche Akademie der Wissenschaften, Wien. March* 5, 1898.

The earthquake commission of the above Academy inquired respecting the cost of a seismometer.

I replied stating the price of instrument and its accessories, gave the address of the maker, and sent the Toronto Report for 1897.

31. *Australia: Melbourne. The Observatory.*—P. BARACCHI, Esq.

The Director of the above observatory wrote on February 1, 1898, in reply to the circular issued by our committee that he had applied to the Victorian Government to take part in our work, and had laid the matter before Section A of the Australian Association for the Advancement of Science. It is hoped that co-operation may be extended to us in the early future.

The following abstract of a report of the Seismological Committee of the Australian Society for the Advancement of Science is taken from 'Symons' Monthly Meteorological Magazine,' March 1898, p. 26 :—

'*Seismological Committee.*

'This report was presented by the Secretary, Mr. George Hogben, M.A., of Timaru, New Zealand, and stated that the most interesting result of the labours of the observers was the fact, based upon rough calculations, that the great South Australian earthquake of May 10, 1897, proceeded from a line parallel to the coast near Beachport and Kingston, and was possibly due to a sliding of one part of the crust upon another, such as forms what is called in geology a "fault." This was probably deep, but the later and slighter shocks were surface ones, caused by readjustments of the immediate crust. The subject was still under investigation by the Secretary. But Mr. Hogben pointed out that it was as part of a world-system of seismological observations that the work of the Committee might be most useful. An international seismological committee had been set up, embracing all the ablest workers in every part of the world, and in co-operation with that committee were committees of the British Association and of the Royal Society. They desire especially to be able to track the microseismic vibrations or minute earthquake waves, which travelled from the sources of disturbance all round the earth's surface, or it might be right through the solid mass of our world (if it is solid). The speed of these finer waves was many times greater than that of the larger waves felt by us, reaching a velocity as great as 12 miles per second, or even more. For the purpose of observing them the international committee had agreed upon a certain type of instrument—the horizontal pendulum—

to be used by all stations alike, as it was important that instruments of the same kind and of the same degree of sensitiveness should be employed for purposes of comparison.'

32. *Norway: Hammerfest.*

Dr. F. Nansen very kindly offered his co-operation in an endeavour to establish the station 'farthest north.'

33. *Ireland: Dublin.*

Professor W. F. Barrett is actively endeavouring to establish a station in Ireland, towards which I understand that Lord Ardilaun has given substantial support.

It is interesting to note that this co-operation, and that referred to in notes (4) and (5), followed lectures bearing on a seismic survey of the world.

II. *Notes on Special Earthquakes.*

34. *Foreign, Colonial, and Indian Offices.*

I was able to inform the Foreign and Colonial Offices that the official notification stating that there had been interruption of two West Indian cables connecting us with Venezuela on December 31 probably referred to the effects of a submarine earthquake, which happened at 11.30 A.M. on December 29 (see p. 214). I received letters of thanks for the information, the correctness of which was not confirmed until March 1.

From the Foreign, Colonial, and Indian Offices I have received many communications relating to the establishment of instruments abroad and other matters connected with the work of this committee. These are referred to under other sections.

35. *Correspondence respecting Earthquakes in the West Indies.*

Mr. Secretary Chamberlain directed that the following two despatches should be sent to me, adding that if I were disposed to interest myself in the matter he would take steps to obtain information on points about which it might be deemed worth while to make inquiry. The first despatch is from the Governor of the Leeward Islands, and the second from the Administrator of Montserrat:—

Springfield House, St. Kitts:
February 28, 1898.

SIR,—I have the honour to transmit to you the duplicate of a despatch from the Commissioner of Montserrat reporting that several severe shocks of earthquake have recently occurred in that island, which have caused considerable damage to buildings, although it does not appear that any lives have been sacrificed.

2. Mr. Baynes remarks in paragraph 5 of his despatch that these shocks of earthquake have been of frequent occurrence since the floods of November, 1896; a fact to which I have had occasion to refer in previous correspondence.

3. What has caused this to be the case I am not prepared to say; but I agree with Mr. Baynes that the subject is one of peculiar interest, and I should be glad if it could form the subject of scientific investigation.

I have, &c.,
F. Fleming.

The Right Hon. Joseph Chamberlain, M.P., P.C.

Commissioner's Office, Montserrat:
February 21, 1898.

Sir,—On Tuesday, the 15th instant, severe shocks of earthquake occurred in this island, which have since been followed by shocks of nearly equal severity, and have caused considerable damage to buildings.

2. The principal shock was at 11.16 A.M. on Tuesday, and was the most severe I have ever experienced. This was followed by shocks so numerous as to seem almost continuous until 3.45 P.M., when there was one of equal severity but shorter duration; and during the rest of the day and the following night numerous shocks continued to be felt. On Friday, at 7 A.M. and 4.25 P.M., and on Sunday, at 9.20 A.M., very severe shocks occurred, and in the intervals minor shocks have been of constant occurrence.

3. The windmill tower at Gage's Estate has been seriously damaged, and the chimneys on the Grove, Dagenham's, Weeke's, Gage's, Paradise, and White's Estates have sustained injury. One house at Gage's has been so much damaged as to be made uninhabitable, and several houses in various localities have been injured. St. George's Church and St. Anthony's Church and Rectory have also sustained some damage.

4. The only serious damage to any Government building has been at the Poor House, where the walls of a small detached building have been so seriously damaged that it has been necessary to remove the inmates. There are cracks in the walls of the Court House and Treasury, but these appear to be superficial. On the public roads, especially those of recent construction, large quantities of earth and boulders have been shaken from the cliffs on to the roadway, but no further damage is reported. Several breaks in the water pipes supplying the town occurred through landslips in the ravines through which the pipe track passes, but these injuries were at once repaired.

5. These shocks of earthquake have been of frequent occurrence since the flood of November, 1896, and in my letter of May 3 last I gave some account of them up to that date. Of late they have greatly increased in severity. Some months ago a number of shocks occurred in Guadeloupe, but I have no recent information from that island. With this exception they have not been felt in the neighbouring islands. They would therefore appear to be of local origin, and some disturbance of the volcanic springs in Gage's Mountain has evidently taken place. The subject is one of peculiar interest, and seems to be well deserving of scientific investigation.

I have, &c.,
Edward Baynes,
Commissioner.

His Excellency Sir F. Fleming, K.C.M.G.

The following two letters bearing on the same subject are also of interest:—

Richmond Hill, Montserrat, West Indies:
March 2, 1898.

DEAR SIR,—I beg to inform you that since the flood of November 29, 1896, which caused great injury to life and property in this island, innumerable shocks of earthquake have been experienced.

There are in this island several craters and sulphur springs, and there are also a few hot-water springs, all of which go to prove that the volcanoes here are by no means extinct, and it is thought by some persons that the mouth of one of the numerous craters has been filled up by a landslip caused by the above-mentioned flood, on the night of which there were several shocks of earthquake—the first experienced in Montserrat for a great number of years. It is possible that the filling up of this crater has been the cause of all the earthquakes we have been feeling here lately.

Since November 1896 there have been experienced at least one thousand shocks of earthquake.

The most severe shocks took place on the following dates:—November 29, 1896; April 22, 24, 25 and 29, 1897; July 28, 1897; December 4, 1897; February 15, 18 and 20, 1898. Those on February 15 exceeded all the others in point of severity. Some persons state that there were eighty-one shocks that day, of which forty-one were felt in three hours.

The shock on April 29, 1897, though one of the longest, was felt throughout this portion of the West Indies, but was of slight force, and, notwithstanding its very long duration, did no injury here, though a great deal of damage was done at Pointe-à-Pitre, in the neighbouring French island of Guadeloupe.

All the other earthquakes have been entirely local, having not even been noticed at Antigua, an island about thirty miles away, though those in April were felt at the isolated rock of Redonda, a few miles off the north coast of this island.

Only the most severe earthquakes have been mentioned above; but scarcely a day passes without our feeling a few shocks, and excluding February 15 as many as thirty shocks have been felt in one day.

During the last month or two the smell of sulphur from the craters has been very strong and disagreeable, silver tarnishing in town very easily.

All the earthquakes seem to have had the same direction, viz., from 'Gage's' Mountain, where the Soufrière is located (see Admiralty Chart of Montserrat), with the exception of that of April 29, which appeared to come from the direction of Guadeloupe, viz., the south.

I am thankful to say that the shocks are usually of very short duration, averaging four or five seconds.

Some of the oldest inhabitants of the island affirm that the worst shock, on February 15 (11.16 A.M.), was just as *severe* as the great earthquake of 1843, but being of shorter duration did not do so much damage.

Several buildings have been very badly damaged. Innumerable cracks have appeared in nearly every stone building in the island, including the Court Hall and the churches.

These shocks of earthquake, which have been continually felt for the last sixteen months (*i.e.* since November 1896), are causing great anxiety among the inhabitants, and it is not known but that they may culminate either in a volcanic eruption or the numerous stone buildings, weakened as they already are by these continual shocks, must in course of time be thrown to the ground unless the earthquakes cease.

The whole subject seems well deserving of scientific investigation. The Government of the island is in a very bad financial state, and could not afford any pecuniary aid to an investigation, though it would doubtless give as much encouragement as possible to the investigators ; but probably in the interests of science your committee or some other scientific society would bear the expense of making a scientific investigation which would be most interesting to science in general.

Official reports in connection with the recent earthquakes have doubtless been sent to the Secretary of State for the Colonies, and I would suggest your communicating with the Colonial Office in considering the question ; but if your Society cannot send out a scientist I should be glad if the substance of this letter could be published in the English newspapers, and perhaps some scientist would take the matter up.

I am, dear Sir, yours faithfully,
H. DE COURCY HAMILTON,
Fellow of the Royal Colonial Institute.

JOHN MILNE, Esq., Secretary, Seismological Investigation Committee, London.

Extract from Letter of Joseph Sturge, Esq., Wheeley's Road, Birmingham, dated February 3, 1898.

'I think you may be glad to know of a somewhat curious phenomenon that has taken place in a small island in the West Indies, Montserrat, with which I am connected.

'The island is the tip of a submarine mountain : it is 12 miles long by 7 wide, and 3,000 feet high. The sea is 2,000 fathoms deep all round the island. There are sulphureous springs of hot water which emit vapour, but no more active volcanic action, and for forty years there have been no serious earthquakes and very few noticeable ones.

'On November 29, 1896, there was an extraordinary rain-storm, 20 inches of rain falling in the centre of the island in about twelve hours. Since that time the island has been subject to constantly recurring slight shocks of earthquake. They come almost every day, and sometimes several in a day. They do not do much harm, but keep people more or less in a state of alarm, and the curious problem is what happened on the day of the rain-storm that *set the earthquakes going.*

'The sulphur springs have emitted a much more copious volume of gas since the change, so that silver now goes black three miles off.

'It may be worth while to mention that in 1880 there was a similar flood in the neighbouring island of St. Kitts, and that the same night there was a volcanic disturbance in Dominica (150 miles from St. Kitts), and a boiling lake came into existence among the mountains there.'

On April 15 Mr. Sturge writes that the earthquakes increased in frequency and violence until the end of February. Almost all stone buildings were more or less injured. Since then there has been a great drought, coincidently with which the shocks have almost entirely ceased. Is this a *propter hoc* or only a *post hoc* ?

III.—*Catalogue of Earthquakes recorded by a Gray-Milne Seismograph at the Central Meteorological Observatory, Tokio, December* 17, 1897, *to January* 27, 1898. (*Continuation of Catalogue commencing in the British Association Report*, 1886.

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			1896.							
			H. M. S.	M. S.						
1,816	XII.	17	1 17 25 A.M.	0 47	S.S.E., N.N.W.	0·2	1·9	0·2	0·4	quick
1,817	„	17	6 14 06 P.M.	—	—	—	—	—	—	slight
1,818	„	20	5 03 38 A.M.	—	—	—	—	—	—	„
1,819	„	29	7 06 06 A.M.	—	—	—	—	—	—	„
			1897.							
1,820	I.	8	5 57 25 A.M.	—	—	—	—	—	—	slight
1,821	„	9	9 27 18 A.M.	—	—	—	—	—	—	„
1,822	„	13	6 39 39 A.M.	—	—	—	—	—	—	„
1,823	„	16	10 58 52 A.M.	—	—	—	—	—	—	„
1,824	„	17	0 49 28 A.M.	3 32	N.E., S.W.	0·7	4·0	0·2	0·3	clocks stopped, slow
1,825	„	17	5 36 36 A.M.	—	—	—	—	—	—	slight
1,826	„	18	9 27 03 P.M.	—	—	—	—	—	—	„
1,827	„	20	10 46 22 A.M.	—	—	—	—	—	—	„
1,828	„	23	2 12 42 P.M.	—	—	—	—	—	—	„
1,829	„	25	1 48 55 P.M.	—	—	—	—	—	—	„
1,830	„	27	3 46 38 P.M.	—	—	—	—	—	—	„
1,831	II.	1	10 33 35 P.M.	—	—	—	—	—	—	„
1,832	„	4	2 13 46 P.M.	—	—	—	—	—	—	„
1,833	„	4	3 51 56 P.M.	—	—	—	—	—	—	„
1,834	„	7	4 38 33 P.M.	5 47	N.W., S.E.	0·7	1·7	—	—	weak, slow
1,835	„	8	5 25 17 A.M.	—	—	—	—	—	—	„
1,836	„	8	8 07 51 A.M.	—	—	—	—	—	—	„
1,837	„	9	10 1 35 P.M.	—	—	—	—	—	—	„
1,838	„	11	0 52 18 A.M.	—	—	—	—	—	—	„
1,839	„	11	7 24 12 A.M.	—	—	—	—	—	—	„
1,840	„	13	2 19 11 A.M.	—	—	—	—	—	—	„
1,841	„	17	9 13 56 P.M.	—	—	—	—	—	—	„
1,842	„	18	8 11 30 P.M.	—	—	—	—	—	—	„
1,843	„	20	9 52 28 P.M.	—	—	—	—	—	—	„
1,844	„	21	0 04 17 P.M.	—	—	—	—	—	—	„
1,845	„	28	1 14 58 A.M.	2 22	N.N.W., S.S.E.	1·4	3·1	0·4	0·2	„
1,846	III.	5	1 14 20 P.M.	—	—	—	—	—	—	„
1,847	„	5	5 27 41 P.M.	0 37	S.W., N.E.	0·2	0·6	0·1	0·1	quick
1,848	„	6	5 36 12 A.M.	—	—	—	—	—	—	slight
1,849	„	7	3 22 46 P.M.	—	—	—	—	—	—	„
1,850	„	13	10 14 55 A.M.	—	—	—	—	—	—	„
1,851	„	14	2 06 25 P.M.	—	—	—	—	—	—	„
1,852	„	17	6 13 58 A.M.	—	—	—	—	—	—	„
1,853	„	20	5 32 34 A.M.	—	—	—	—	—	—	„
1,854	„	26	2 11 57 A.M.	—	—	—	—	—	—	„
1,855	„	27	7 49 26 P.M.	—	—	—	—	—	—	„
1,856	„	30	9 16 41 P.M.	—	—	—	—	—	—	„
1,857	IV.	3	8 30 45 A.M.	—	—	—	—	—	—	„
1,858	„	4	3 32 38 A.M.	—	—	—	—	—	—	„
1,859	„	13	3 47 52 A.M.	—	—	—	—	—	—	„
1,860	„	16	0 13 37 A.M.	—	—	—	—	—	—	„
1,861	„	16	3 42 08 A.M.	—	—	—	—	—	—	„
1,862	„	24	9 48 49 P.M.	—	—	—	—	—	—	„
1,863	„	27	10 31 54 P.M.	—	—	—	—	—	—	„
1,864	„	30	4 03 06 P.M.	—	—	—	—	—	—	„
1,865	V.	3	4 42 59 A.M.	—	—	—	—	—	—	„
1,866	„	3	6 29 39 A.M.	—	—	—	—	—	—	„
1,867	„	4	11 36 47 P.M.	—	—	—	—	—	—	„
1,868	„	5	8 57 21 P.M.	—	—	—	—	—	—	„
1,869	„	6	6 46 35 A.M.	—	—	—	—	—	—	„
1,870	„	6	7 34 0 A.M.	—	—	—	—	—	—	„
1,871	„	6	9 40 51 A.M.	—	—	—	—	—	—	„
1,872	„	6	7 53 43 P.M.	—	—	—	—	—	—	„
1,873	„	7	2 59 15 A.M.	—	—	—	—	—	—	„
1,874	„	9	11 01 09 A.M.	—	—	—	—	—	—	„

Catalogue of Earthquakes—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,875	V.	12	3 30 11 A.M.	—	—	—	—	—	—	slight
1,876	"	12	6 19 36 P.M.	—	—	—	—	—	—	"
1,877	"	13	2 28 59 P.M.	—	—	—	—	—	—	quick
1,878	"	18	10 09 49 A.M.	—	—	—	—	—	—	slight
1,879	"	19	6 25 13 A.M.	—	—	—	—	—	—	"
1,880	"	23	9 23 0 P.M.	3 40	N.W., S.E.	1·7	1·7	—	—	slow
1,881	"	27	10 25 32 A.M.	—	—	—	—	—	—	slight
1,882	VI.	11	9 59 31 A.M.	—	—	—	—	—	—	"
1,883	"	13	11 24 14 A.M.	—	—	—	—	—	—	"
1,884	"	18	1 23 40 P.M.	—	—	—	—	—	—	"
1,885	"	19	2 03 43 A.M.	—	—	—	—	—	—	"
1,886	"	22	1 22 18 P.M.	—	—	—	—	—	—	"
1,887	"	27	5 48 23 A.M.	1 12	S.E., N.W.	slight		slight		quick
1,888	VII.	8	11 33 44 P.M.	—	—	—	—	—	—	slight
1,889	"	21	10 12 52 P.M.	—	—	—	—	—	—	"
1,890	"	22	9 54 53 A.M.	—	—	—	—	—	—	"
1,891	"	22	6 31 44 P.M.	4 34	W.S.W., E.N.E.	1·3	7·3	0·2	0·3	slow, weak
1,892	"	22	6 50 57 P.M.	—	—	—	—	—	—	slight
1,893	"	28	3 30 50 P.M.	—	—	—	—	—	—	"
1,894	"	29	6 34 59 A.M.	—	—	—	—	—	—	"
1,895	"	29	6 57 46 A.M.	—	—	—	—	—	—	"
1,896	"	29	10 31 54 A.M.	—	—	—	—	—	—	"
1,897	"	29	10 44 50 P.M.	1 50	N.N.W., S.S.E.	0·7	0·7	slight		"
1,898	"	31	6 51 30 A.M.	—	—	—	—	—	—	"
1,899	VIII.	2	2 02 47 A.M.	—	—	—	—	—	—	"
1,900	"	4	10 19 22 P.M.	—	—	—	—	—	—	"
1,901	"	5	9 12 23 A.M.	abt. 7 0	—	—	—	—	—	slow, weak
1,902	"	5	9 29 22 A.M.	—	—	—	—	—	—	slight
1,903	"	5	9 45 51 A.M.	—	—	—	—	—	—	"
1,904	"	5	10 21 09 A.M.	—	—	—	—	—	—	"
1,905	"	5	10 44 23 A.M.	—	—	—	—	—	—	"
1,906	"	5	11 31 04 A.M.	—	—	—	—	—	—	"
1,907	"	5	4 20 40 P.M.	—	—	—	—	—	—	"
1,908	"	5	6 54 42 P.M.	—	—	—	—	—	—	"
1,909	"	6	3 59 30 A.M.	—	—	—	—	—	—	"
1,910	"	6	4 15 39 A.M.	—	—	—	—	—	—	"
1,911	"	6	8 48 57 A.M.	—	—	—	—	—	—	"
1,912	"	8	4 37 09 A.M.	—	—	—	—	—	—	"
1,913	"	8	11 55 36 A.M.	—	—	—	—	—	—	"
1,914	"	8	6 28 46 A.M.	—	—	—	—	—	—	"
1,915	"	12	10 51 04 A.M.	—	—	—	—	—	—	"
1,916	"	16	11 48 01 A.M.	—	—	—	—	—	—	"
1,917	"	16	4 53 33 P.M.	3 0	N.N.W., E.S.E.	1·0	3	—	—	slow, weak
1,918	"	16	5 36 25 P.M.	—	—	—	—	—	—	slight
1,919	"	16	6 11 35 P.M.	—	—	—	—	—	—	"
1,920	"	18	11 55 27 A.M.	—	—	—	—	—	—	"
1,921	"	21	0 28 16 A.M.	—	—	—	—	—	—	"
1,922	"	21	6 29 28 A.M.	—	—	—	—	—	—	"
1,923	"	22	0 23 58 A.M.	—	—	—	—	—	—	"
1,924	"	25	5 14 33 A.M.	—	—	—	—	—	—	"
1,925	"	27	1 08 46 A.M.	—	—	—	—	—	—	"
1,926	"	27	6 19 20 A.M.	—	—	—	—	—	—	"
1,927	"	27	8 46 19 A.M.	—	—	—	—	—	—	"
1,928	"	28	4 02 0 P.M.	—	—	—	—	—	—	"
1,929	IX.	8	11 44 36 A.M.	1 15	N.N.E., S.S.W.	0·8	0·6	slight		quick, weak
1,930	"	11	1 40 13 P.M.	—	—	—	—	—	—	slight
1,931	"	21	9 02 12 A.M.	—	—	—	—	—	—	"
1,932	"	23	6 27 03 A.M.	—	—	—	—	—	—	"
1,933	"	26	9 59 18 P.M.	—	—	—	—	—	—	"
1,934	X.	2	9 45 19 P.M.	3 25	W.S.W., E.N.E.	1	1·8	0·4	0·2	quick, weak
1,935	"	7	1 40 02 P.M.	—	—	—	—	—	—	slight
1,936	"	13	5 16 57 P.M.	—	—	—	—	—	—	"
1,937	"	15	10 57 47 P.M.	—	—	—	—	—	—	"
1,938	"	17	7 54 05 P.M.	—	—	—	—	—	—	"
1,939	"	20	3 01 18 P.M.	2 0	S.E., N.W.	0·3	1·0	0·2	0·3	weak, quick
1,940	"	25	10 11 10 A.M.	0 50	N.N.W., S.S.E.	0·2	0·5	—	—	quick
1,941	"	26	10 18 39 P.M.	—	—	—	—	—	—	slight
1,942	XI.	2	1 42 26 A.M.	—	—	—	—	—	—	"

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Day	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion.		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,943	XI.	5	6 44 11 A.M.	—	—	—	—	—	—	slight
1,944	„	9	9 39 28 A.M.	—	—	—	—	—	—	„
1,945	„	11	5 29 53 A.M.	—	—	—	—	—	—	„
1,946	„	13	3 06 36 A.M.	—	—	—	—	—	—	„
1,947	„	13	6 16 24 A.M.	—	—	—	—	—	—	„
1,948	„	14	9 13 43 A.M.	—	—	—	—	—	—	„
1,949	„	15	6 06 39 A.M.	—	—	—	—	—	—	„
1,950	„	16	8 03 16 A.M.	—	—	—	—	—	—	„
1,951	„	19	10 16 22 A.M.	—	—	—	—	—	—	„
1,952	„	20	3 05 01 A.M.	—	—	—	—	—	—	„
1,953	„	22	10 04 36 A.M.	—	—	—	—	—	—	„
1,954	„	23	5 56 54 P.M.	—	—	—	—	—	—	„
1,955	„	24	9 06 54 A.M.	—	—	—	—	—	—	„
1,956	„	27	0 12 56 A.M.	—	—	—	—	—	—	„
1,957	XII.	2	11 23 15 P.M.	—	—	—	—	—	—	„
1,958	„	3	9 24 0 A.M.	—	—	—	—	—	—	„
1,959	„	4	9 18 10 A.M.	1 14	S.S.W., N.N.E.	0·8	0·5	—	—	quick
1,960	„	5	8 08 21 A.M.	—	—	—	—	—	—	slight
1,961	„	6	2 03 45 A.M.	—	—	—	—	—	—	„
1,962	„	7	5 25 31 P.M.	—	—	—	—	—	—	„
1,963	„	8	5 23 11 P.M.	—	—	—	—	—	—	„
1,964	„	10	8 04 42 P.M.	—	—	—	—	—	—	„
1,965	„	12	6 40 49 A.M.	—	—	—	—	—	—	„
1,966	„	13	10 57 57 P.M.	—	—	—	—	—	—	„
1,967	„	16	8 47 43 P.M.	—	—	—	—	—	—	„
1,968	„	17	9 26 19 P.M.	—	—	—	—	—	—	„
1,969	„	19	3 16 26 A.M.	—	—	—	—	—	—	„
1,970	„	19	1 21 26 P.M.	—	—	—	—	—	—	„
1,971	„	21	5 14 41 A.M.	—	—	—	—	—	—	„
1,972	„	23	3 36 11 A.M.	—	—	—	—	—	—	„
1,973	„	23	8 45 53 A.M.	—	—	—	—	—	—	„
1,974	„	23	0 26 04 P.M.	—	—	—	—	—	—	„
1,975	„	23	11 03 27 P.M.	—	—	—	—	—	—	„
1,976	„	24	3 36 26 P.M.	—	—	—	—	—	—	„
1,977	„	26	4 41 25 P.M.	3 20	S.E., N.W.	1·2	1·4	—	—	weak, slow
1,978	„	31	11 52 14 P.M.	—	—	—	—	—	—	slight
					1898.					
1,979	I.	5	5 21 01 P.M.	—	—	—	—	—	—	„
1,980	„	13	8 16 22 A.M.	—	—	—	—	—	—	„
1,981	„	14	2 30 06 A.M.	—	—	—	—	—	—	„
1,982	„	27	10 43 27 P.M.	—	—	—	—	—	—	„

IV.—EARTHQUAKES RECORDED AT SHIDE, AND ALSO AT OTHER STATIONS.

Earthquakes recorded with a Milne Horizontal Pendulum at Shide, Isle of Wight, 1897–98. The time used is Greenwich mean (civil) time. Midnight = 24 or 0 hours. P.T.s = preliminary tremors. Duration means the interval of time over which movements continued.

An asterisk (*) indicates Earthquakes which are discussed separately, or of which seismograms are reproduced.

No.	Date	Time of Commencement	Remarks
		1897.	
		H. M. S.	
96*	Mar. 23	16 19 12	Small.
97*	May 5	22 44 20	„
98*	„ 9	23 50 38	Large. Exact commencement lost. P.T.s at least 3m. Duration 47m.

EARTHQUAKES RECORDED AT SHIDE, ETC.—*continued.*

No.	Date		Time of Commencement	Remarks.
99*	May	13	12 16 24	Moderate. P.T.s 6m. Duration 36m.
100*	,,	23	13 15 20	Small.
101*	,,	24	0 18 59	Moderate.
102*	,,	24	1 48 19	Small.
103*	,,	24	4 30 59	,,
104*	June	3	9 57 18	Large. P.T.s 17m. Duration 2h.
105*	,,	12	11 29 10	Large. Exact commencement lost. Period of large waves 15s. Range 10mm. Origin, Assam. P.T.s exceed 10m.
106*	,,	12	19 53 19	Small. Duration 10m.
107*	,,	13	7 39 33	,, ,, 7m.
108*	,,	13	10 51 33	,, ,, 10m. Three maxima.
109	,,	20	20 58 40	,, ,, 16m.
110	,,	21	20 14 43	,, ,, 8m.
111	,,	22	14 11 40	,, ,, 8m.
112*	,,	24	19 34 53	Ends 20h. 43m. 15s. Large. Origin, Albania.
113*	,,	30	4 39 33	Small.
114*	,,	30	15 0 2	Slight. Origin, Epirus.
115*	July	17	7 57 9	Small.
116*	,,	21	13 33 32	Very large. P.T.s 7m. Two large maxima.
117*	,,	22	11 20 0	Moderate. Commencement lost.
118*	Aug.	2	15 46 39	Small.
119*	,,	5	0 22 35	Very large. P.T.s 30m. Duration over 3h. Origin, Japan.
120*	,,	16	8 6 29	Slight. Ends 8h. 56m. 22s.
121	,,	17	6 41 17	Small.
122*	,,	26	17 1 41	,,
123*	,,	26	21 40 30	,,
124*	,,	26	22 13 14	Moderate. P.T.s 2m. 44s.
125	,,	29	6 16 17	,, ,, 4m.
126	,,	31	15 4 19	Small.
127	Sept.	1	18 29 41	,,
128	,,	5	1 21 59	,,
129	,,	5	1 36 50	,,
130	,,	12	22 54 18	,,
131*	,,	17	15 59 58	Large. P.T.s 8m. Duration 40m.
132*	,,	17	17 59 58	,, ,, 8m. ,, 38m.
133*	,,	20	19 24 47	,, ,, 40m. ,, 2h. 56m. Origin, E. of Borneo.
134*	,,	21	5 28 51	Large. P.T.s 43m. Duration 2h. 56m. Origin, E. of Borneo.
135*	,,	21	11 36 44	Slight. Ends 13h. 20m. 20s.
136	,,	24	23 58 56	Small.
137	,,	25	18 3 39	,,
138*	Oct.	2	13 36 39	Moderate. Duration 27m.
139*	,,	3	15 7 9	Small.
140*	,,	19	0 6 52	Large. P.T.s 41m. Duration 2h. 30m.
141*	,,	20	14 43 29	,, ,, 42m. ,, 2h. 33m.
142*	,,	23	3 19 0	Slight. Ends 3h. 28m. 29s.
143	,,	23	17 49 56	Small.
144	,,	31	2 0 0	About this time. Small.
145	,,	31	17 0 0	,, ,, ,, Large.
146*	Nov.	14	14 53 35	Small. Duration 22m.
147	,,	17	3 28 47	,,
148	,,	20	17 33 21	,,
149	,,	22	8 or 9 48 45	,,
150	,,	23	4 56 44	,,
151	,,	23	9 34 22	,,

EARTHQUAKES RECORDED AT SHIDE, ETC.—*continued.*

No.	Date	Time of Commencement	Remarks
152*	Nov. 25	10 1 48	Large. Ends 12h.
153*	Dec. 11	10 4 31	Small. Duration 45m.
154	„ 17	10 20 58	Moderate.
155*	„ 17	18 30 0	Slight. Ends 10m. 30s. on 18th.
156*	„ 28	20 54 21	Moderate. P.T.s 8m. Duration 24m. Observed in Toronto at 20h. 24m. 37s.
157*	„ 29	11 40 48	Large. P.T.s 19m. Duration 1h. 22m. 28s. Origin, N. of Hayti. Observed in Toronto 11h. 32m. 29s.
158*	—	—	Dec. 29 to Jan. 1, slight tremors.
		1898.	
159	Jan. 3	14 41 2	Small.
160	„ 3	15 7 15	„
161*	„ 24	23 45 49	Large. P.T.s 16m. Duration 33m. On smoked paper, NS component, 8m. 34s. Toronto, 13m. 30s. on the 25th.
162*	„ 29	13 44 8	Small. P.T.s 5m. 47s. Duration 13m. 1s.
163*	„ 29	15 5 25	Large. P.T.s 9m. 30s. Duration 1h. 1m. Smoked paper, NS component, 15h. 5m. 26s.
164*	Feb. 5	8 36 13	End 9h. 19m. 28s. Record on smoked paper.
165	„ 7	23 35 20	Small.
166	„ 8	1 47 32	„
167	„ 8	23 5 47	„
168	„ 9	22 57 36	„ Duration 15m.
169	„ 16	17 9 8	„ and three others within 54m.

NOTE.—On February 5, about 9 A.M., when there were slight disturbances in Catania, Catanzaro (Calabria), Rome, and Livorno, and February 18, between 16h. 30m. and 17h. 30m., when there were feeble movements recorded at Catania, Ischia, Rocca di Papa, and Rome. The clock driving the photographic film at Shide had stopped. On the 5th it will be observed that a record was obtained on smoked paper.

Note on the Edinburgh Bifilar. Extracted from a Letter received from Mr. THOMAS HEATH, *of the Royal Observatory, Edinburgh.*

An inspection of the photograph shows but little trace of the diurnal wave. Measurements of the change of position of the light spot for every four hours throughout the month of March 1898 results in an irregular curve, which apparently indicates a slight movement to the north from noon to midnight, and to the south from midnight to noon. Maximum and minimum thermometers are being established in the bifilar room.

The mean of daily measurements between February 28 and April 2 indicate that the new movement of the light spot corresponds to a tilt of $1''\cdot 74$ of the frame. The photographs have not been subjected to the examination necessary to show whether there is a lunar effect.

The instrument was first mounted in March 1894, at Carlton Hill, and removed to its present site, on Blackford Hill, in October 1895. It was mounted with photo-recording apparatus in August 1896. A second pendulum purchased out of grant from the Scientific Research Committee of the Royal Society was mounted in May 1898.

Movements recorded by a Darwin Bifilar Pendulum at the Royal Observatory, Edinburgh. Director, Dr. R. Copeland.

The instrument was presented to the Observatory by the late M. Antoine d'Abbadie in 1894.

No.	Shide No.	Date	Time, G.M.T.	Remarks
			H. M. S.	
1	104	June 3	10 57 0	Slight oscillations and widening of line.
2	105	„ 12	11 18 0	Ends at 13h. 12m.
3	116	„ 21	13 40 0	Fine oscillatory disturbance until 14h. 4m.
4	119	Aug. 5	1 2 30	Fine oscillatory disturbance until 1h. 40m. 30s.
5	131	Sept. 17	15 55 0	Small oscillatory disturbance until 16h. 5m.
6	132	„ 17	18 2 0	Small oscillatory disturbance until 18h. 12m.
7	133	„ 20	19 56 0	Small oscillatory disturbance until 20h. 28m. Smaller oscillations 20h. 17m. to 20h. 28m.
8	134	„ 21	6 7 30	Like preceding until 6h. 38m. 30s.
9	139	Oct. 3	14 58 0	Very slight tilt to N.
10	140	„ 19	0 28 0	Small oscillatory disturbance until 50m.
11	141	„ 20	15 20 0	Small oscillatory disturbance until 15h. 33m.
12	146	Nov. 14	15 29 0	Tilt to N.
13	163	Jan. 29	15 15 0	Small oscillatory disturbance until 15h. 25m.

Observations at Rocca di Papa. By Dr. A. Cancani.

Instruments described on pp. 264–266.

No.	Shide No.	Date	Commencement	Maximum	Remarks
		1897	H. M. S.	H. M. S.	
1	100	May 23	—	13 17 10	Small undulation.
2	104	June 3	9 54 30	10 34 0	End at 10h. 40m. Period 24s.
3	105	„ 12	11 18 0	11 47 10	At 11h. 36m. Period 16s.
4	116	July 21	—	13 50 0	At 13h. 45m. Period 10s.
5	117	„ 22	—	11 26 0	—
6	119	Aug. 5	0 32 40	1 8 30	End 2h. 12m.
7	122	„ 26	16 46 30	17 0 0	Period 18s.
8	124	„ 26	22 8 30	22 15 30	End 22h. 30m.
9	131	Sept. 17	15 50 0	15 55 0	Period 18s.
10	132	„ 17	17 48 0	18 6 0	—
11	133	„ 20	19 25 0	19 40 0	Period 18s. End 21h. 5m.
12	134	„ 21	5 32 8	5 46 0	End 7h.
13	140	Oct. 19	0 5 30	0 51 0	Period 32s. At 25m. End 1h. 15m.
14	141	„ 20	15 0 0	15 30 0	End 17h. Period 16s.
15	157	Dec. 29	11 56 0	12 5 30	End 12h. 23m. E.W. component large. N.S. small.
		1898			
16	161	Jan. 24	23 49 0	0 15 15	End 45m., January 25
17	162	„ 29	13 39 0	13 39 17	End 13h. 45m. E.W. component.
—	—	—	13 40 0	—	End 13h. 40m. 30s. N.S. component small.
18	163	Jan. 29	15 5 15	15 11 0	Max. in P.Ts. 15h. 9m. 50s. Waves commence 15h. 10m. 45s.
—	—	—	—	15 11 45	End 15h. 40m. for E.W.
—	—	—	—	15 13 30	N.S. component not so distinct.

Records from W. E. Plummer, Esq., Liverpool Observatory, Bidstone, Birkenhead. Instrument a Darwin Bifilar Pendulum, provided by the British Association.

No.	Shide No.	Date	Time	Remarks
			1897.	
			H. M. H. M.	
1	—	Sept. 6	12 20 to 12 25	Small.
2	132	„ 17	18 10 „ 18 19	Very small.
3	—	„ 19	7 22 „ 7 30	Small. September 20 to 22 records not taken.
4	—	„ 23	12 4 „ 12 20	Motion 0″·008.
5	—	„ 24	15 3	Small. September 28 to October 1 records not taken.
6	139	Oct. 3	16 50 „ 16 55	Small. October 24 to 26, records imperfect.
7	—	„ 27	17 55 „ 18 30	Slight disturbance. October 29 to November 21 instrument dismounted.
8	—	Nov. 24	11 21 „ 11 31	Displacement 0″·12.
9	—	„ 26	15 30 „ 16 40	Slight and irregular.
10	—	„ 27	14 0 „ 19 0	„ „ „
11	—	Dec. 5	14 30 „ 15 10	Slight.
12	153	„ 11	9 50 „ 11 10	„
13	—	„ 14	10 30 „ 14 30	Displacement 0″·1.
14	157?	„ 29	8 30 „ 9 0	Slight disturbance.
			1898.	
15	—	Jan. 7	2 0 „ 2 10	Very slight. January 20 to 22 clock stopped.
16	—	„ 24	14 0	Uncertain and very slight.
17	—	Feb. 2	9 50 „ 11 30	Moderate.
18	—	„ 6	18 4 „ 18 10	Slight.
19	—	„ 7	13 0 „ 15 0	„ movement.
20	169	„ 16	17 30	„ „
21	—	„ 18	15 25 „ 16 30	„ „
22	—	„ 20	3 0 „ 8 0	Most considerable disturbance. Motion 0″·17.
23	—	„ 20	18 30	Disturbance.
24	—	„ 24	14 22 „ 14 40	Slight.
25	—	Mar. 2	0 11 „ 0 30	Moderate. On 15th no record.
26	—	„ 7	14 0 „ 18 0	Trace irregular.
27	—	„ 8	4 0 „ 8 0	„ „
28	—	„ 11	17 0 About	Slight.
29	—	„ 12	2 0 „ 4 0	Slight
30	—	„ 24	8 20 „ 15 0	Trace irregular.
31	—	„ 27	5 0 „ Noon	„ „
32	—	„ 27	20 50 „ 21 23	Slight.
33	—?	„ 28	12 0 „ 12 40	Moderate.

Records received from Professor Kortazzi, Nicolaiew. The recording instrument was a von Rebeur-Paschwitz Horizontal Pendulum. Max = maximum. Dur = duration.

No.	Shide No.	Date	Commencement G.M.T.			Remarks
		1897	H.	M.	S.	
1	97	May 5	22	12	0	Max. 22h. 27m. Dur. 1h.
2	99	,, 13	12	2	0	Very large. P.T.s 18m. Dur. 2h. 8m.
3	100	,, 23	12	48	0	Moderate. Max. 13h. 9m. Dur. 59m.
4	101	,, 24	23	57	0	Large. P.T.s 9m. Max. 20m. Dur. 1h. 4m.
						No observations from June 3 to 29.
5	113	June 30	3	50	0	Moderate. Max. 4h. 16m. Dur. 44m.
6	115	July 17	7	48	0	Small. Max. 7h. 50m. 5s. Dur. 26m.
7	116	,, 21	13	43	0	Large. Dur. 35m. P.T.s 4m.
8	117	,, 22	9	52	0	,, ,, 67m. ,, 11m.
9	118	Aug. 2	15	29	0	Small. ,, 10m.
10	119	,, 5	0	17	0	Very large. Max. 31m. Dur. 3h. 35m.
11	122	,, 26	16	32	0	Small. Max. 16h. 46m. Dur. 45m.
12	123	,, 26	21	40	0	,, ,, 21h. 57m. ,, 42m.
13	131	Sept. 17	15	40	0	Very large. Max. 15h. 45m. Dur. 44m. Origin, Tashkent.
14	132	,, 17	18	0	0	Small. Details lost.
15	133	,, 20	19	23	30	Very large. Max. 19h. 29m. 5s. Dur. 4h.
16	134	,, 21	4	57	0	Very large. Max. 5h. 7m. The end lost.
17	138	Oct. 2	12	56	30	,, ,, Max. 13h. 30m. Dur. 1h. 36m.
18	140	,, 19	0	13	0	Very large. Max. 42m. Dur. 3h. 1m. P.T.s 7m.
19	141	,, 20	14	49	0	Very large. Max. 15h. 37m. Dur. 3h. 4m. P.T.s 11m.
20	153	Dec. 11	10	9	0	Moderate. Max. 10h. 28m. Dur. 1h. 10m.
21	156	,, 28	20	53	0	Small. Max. 21h. 4m. 30s. Dur. 29m.
22	157	,, 29	11	47	0	Small. Max. 11h. 55m. and 12h. 7m. Dur. 2h. 5m.
		1898				
23	161	Jan. 24	23	49	30	Very large. Max. 5m. Dur. 37m. 5s.
24	162	,, 29	13	33	0	Small. Dur. 19m.
25	163	,, 29	15	4	0	Very large. Max. 15h. 10m. Dur. 58m.

Earthquakes recorded at Shide and also at Distant Localities.

For a collective statement regarding earthquakes recorded in Italy I am indebted to Professor P. Tacchini, Director of the R. Ufficio Centrale di Meteorologia e di Geodinamica al Collegio Romano, Via del Caravita N° 7, Roma. He writes me that records from Padua have not been received since August 1897.

Professor Stupart's records from the Meteorological Observatory, Toronto, date from December 28, 1897.

The Shide Numbers	Rome	Rocca di Papa	Padua	Sienne	Pavia	Ischia	Italy generally	Catania	Toronto	Edinburgh	Bidstone	Nicolaiew
97												—
99												—
100		—	—			—		—				—
101	—	—	—	—	—	—		—				—
102	—					—						
104	—	—	—	—		—		—		—		
105							—			—		
112	—		—			—						
113												—
114							—					
115												—
116							—			—		—
117		—				—		—				—
118												—
119							—			—		—
120	—	—	—			—		—				
122	—	—				—						—
123	—	—				—						—
124	—	—				—						
131	—	—				—		—		—		—
132	—	—				—		—		—	—	—
133	—	—				—		—		—		—
134	—	—				—		—		—		—
135							—					
138	—							—				—
139										—	—	
140	—	—				—		—		—		—
141	—	—				—		—		—		—
142	—					—		—				
146										—		
152								—				
153								—			—	—
156									—			—
157							—		—		—	—
161							—		—			—
162							—					—
163							—			—		—
164	—							—				

Observations at the R. Osservatorio di Catania e dell' Etna. By Dr. A. Riccò. 1897–1898.

Instrument a long pendulum, p. 259.

No.	Shide No.	Date	Commencement G.M.T. H.	M.	S.	Remarks
1	100	Mar. 23	13	20	6	Small
2	101	„ 24	0	51	46	Small. Also 1h. 0m. 2s. and 1h. 5m. 49s.
3	104	June 3	9	53	42	„ Duration 1h. 35m. 37s.
4	105	„ 12	11	17	22	Very large. Duration 4h. 51m. 38s. Max. range 32mm. Period of large waves 11s.
5	116	July 21	13	39	4	Moderate. P.Ts. 1m. 23s. Duration 1h. 15m. 29s.
6	117	„ 22	9	4	53	Small. Exact commencement lost
7	118	Aug. 2	15	0	17	„ „ „ „
8	119	„ 5	0	24	35	Moderate. P.Ts. 10m. 29s. Duration 2h. 40m. 53s.
9	131	Sept. 17	15	15	50	Small. Duration 2h. 36m. 47s.
10	133	„ 20	19	25	2	„ Period of large waves 11·5s. Duration 2h. 10m. 45s.
11	134	„ 21	5	29	32	Small
12	138	Oct. 2	13	31	51	Small. Period of large waves 11s. Duration 32m. 11s.
13	140	„ 19	0	6	36	Small. Period of large waves 12s. Duration 52m. 42s.
14	141	„ 20	14	49	26	Small
15	153	Dec. 11	9	51	28	Small. P.Ts. 14m. 21s. Duration 1h. 20m. 54s.
16	157	„ 29	11	29	10	Small. Period of large waves 23s. Duration 1h. 30m. 50s.
17	162	Jan. 29	14	4	41	Large. P.Ts. 1h. 2m. 19s. Range 18 mm. Duration 1h. 33m. 51s.

Deductions based on the Preceding Records.

In order to determine the areas over which each of the earthquakes recorded at Shide had been perceptible a list of these (see p. 191) was sent to observatories at the following places :—

Edinburgh,* Bidstone,* Strassburg, Padua, Rome,* Rocca di Papa,* Catania,* Ischia, Nicolaiew,* Charkow, Potsdam,* Toronto.*

Replies have been received from those stations marked with an asterisk. Dr. P. Tacchini, Director of the Ufficio Centrale di Meteorologia e di Geodinamica at Rome, in replying, called my attention to several earthquakes which had been well recorded in Italy, but which did not appear on my list. A re-examination of my seismograms led to the discovery of certain of these, and the numbers on the Shide list were increased from 160 to 169.

Records which ought to be strictly comparable are those from Shide, Toronto, and other stations at which the free horizontal pendulums adopted by this committee have been established.

The records from Strassburg, Nicolaiew, Potsdam, and from stations at which there are free horizontal pendulums of the von Rebeur-Paschwitz or Ehlert types, provided that these instruments have been adjusted with like degrees of sensibility, should also be comparable amongst themselves.

If, however, certain of these instruments have been so arranged that their stability is feeble, or, in other words, so that their free period is large as compared with that of others, they can hardly be expected, even when placed side by side, to yield similar seismograms. A small horizontal pendulum with a period of, say, 50 seconds and a large multiplication may be continuously in movement over a considerable period of time. This being the case, it may often happen that the exact commencement of an earthquake may not be determinable. In the Strassburg records, for example, we find commencements of movement given so many minutes in advance of other stations in Europe that for the present, at least, we are inclined to accept the conclusions to which they lead with some reserve (see Earthquake No. 83).

In Italy there is a great variety of instruments which, for the most part, record with ink upon the surface of paper, or by means of indices writing on smoked paper.

The ordinary pendulums vary in length from a few metres up to 25 metres in length. In Catania, for example, there is a pendulum 25 metres in length, carrying a bob of 300 kgs., and with writing indices multiplying its movements 12·5 times. It appears that these exceedingly long pendulums are sometimes affected by the action of the wind upon the building in which they are suspended. When this occurs it becomes difficult to determine with exactness the time at which an earthquake has its commencement.

The horizontal pendulums are also characterised by their great size. The horizontal booms of such instruments at Rocca di Papa, which carry 25 kgs. near their outer end, are 2·7 metres in length, the tie running to a point 5·25 metres above the foot of each boom. They write with ink on a band of paper moving at a rate of 60 cm., or 2 feet, per hour. The open diagrams obtained from both types of instrument are excellent (see p. 207). Unfortunately, the enormous dimensions of these instruments preclude any extensive adoption by private observers. When these dimensions are reduced, as, for example, with the ordinary pendulums, the smaller of these, not having sufficient multiplication or inertia to overcome the frictional resistance of writing indices, fail in a greater or lesser degree to record the small preliminary tremors, with the result that the time at which an earthquake commences is apparently retarded.

It is probably sometimes this which explains the great difference in the recorded times at which earthquakes originating at great distances have announced themselves at different recording stations in Italy and Europe.

For description of instruments in Italy and at Strassburg see pp. 258–272.

Since writing the Report for 1897 I have obtained a list of records from Japan and the catalogue issued from time to time by Professor Pietro Tacchini in the 'Bollettino della Società Sismologica Italiana.' Materials extracted from these sources enable me to throw further light upon records published in 1897.

No. 1, June 15, 1896. (B.A. Report, 1897.)

This is the disastrous shock the sea waves accompanying which occasioned the loss of nearly 30,000 lives on the N.E. coast of Japan, a description of which will be found in the Report for 1897.

Velocity of Propagation of Earth-waves.

	H.	M.	S.		M.	S.
Time at origin . .	10	31	0			
Padua . . .	10	46	57	Time to travel. . .	15	57
Ischia . . .	10	50	29	,, ,, ,, . .	19	29
Rocca di Papa .	10	56	18	,, ,, ,, . . .	25	18
Catania (about) .	11	0	0	,, ,, ,, . . .	29	0
Rome . . .	11	19	20	,, ,, ,, . . .	48	20

—	Distance on arc kms.	Distance on chord kms.	Velocity on arc km. per sec.	Velocity on chord km. per sec.
Padua	9490	8592	9·9	8·9
Ischia	9879	8910	8·4	7·6
Rocca di Papa . . .	9879	8910	6·5	5·8
Catania	9990	8993	5·7	5·1
Rome	9879	8910	3·4	3·0

Instruments employed.

Padua . .	Microseismograph (Vicentini) Pendulum, 1·5 m. Bob, 50 kgs. Free period, 2·4 secs. Multiplication by indices, 70 to 80.
Ischia . .	Horizontal Pendulum. Bob, 12 kgs. Free period, 11 secs.
Rocca di Papa.	Pendulum, 15 m. Bob, 200 kgs.
Catania . .	Pendulum, 25·3 m. Bob, 300 kgs.
Rome . .	Pendulum, 8 m. Bob, 100 kgs.

No. 83, February 7, 1897. (B.A. Report, 1897).

	H.	M.	S.	Pts. 26 min. 40 secs. Duration, 1 hr. 6 mins.
Strassburg .	7	45	4	Horizontal pendulum and photo record.
Edinburgh .	7	49	7	Bifilar pendulum and photo record.
Padua . .	7	49	30	Pendulum (Vicentini).
Ischia . .	7	50	6	Horizontal pendulum, 12 kgs.
Potsdam . .	7	55	0	Horizontal pendulum and photo record.
Nicolaiew .	7	57	1	,, ,, ,, ,,
Shide . .	7	59	3	,, ,, ,, ,,
Rocca di Papa .	8	20	0	Pendulum, 15 m., 250 kgs.
Catania . .	8	22	43	Pendulum, 25 m., 300 kgs.
Rome . .	8	25	0	Pendulum, 16 m., 200 kgs.
Tokio . .	7	38	33	Duration by seismograph, 5·47. Slow movement.

At Ischia the period of the large waves reached 18·5 secs. The natural period of the pendulums in the meridian and at right angles was 12·9 secs. and 16·4 secs.

At Rocca di Papa there were also two horizontal pendulums carrying 30 kgs., and with periods of 20 secs. The N.S. component commenced at 8 hrs. 25 mins., and the E.W. component at 8 hrs. 23 mins. 40 secs.

At Catania the N.W.–S.E. component commenced at 8 hrs. 22 mins. 43 secs. ; N.E.–S.W. component commenced at 8 hrs. 27 mins. 49 secs.

Velocity of Propagation.—For reasons similar to those given for Earthquake No. 100, I shall assume that this disturbance had the same origin as No. 100, and that it occurred at least 2 mins. 30 secs. earlier than it was noted in Tokio. The time at which it originated is therefore 7 hrs. 36 mins. On this assumption the following table has been calculated :—

—	Time to travel		Distance on arc in degrees and kms.	Distance on chord in kms.	Velocity on arc km. per sec.	Velocity on chord km. per sec.
	M.	S.	°			
Strassburg	9	4	85·2 = 9457	8592	17·0	15·0
Edinburgh	13	7	85·0 = 9435	8592	12·0	10·9
Padua	13	30	85·5 = 9490	8592	11·7	10·6
Ischia	14	6	89·0 = 9879	8910	11·6	10·5
Potsdam	19	0	79·7 = 8846	8172	7·7	7·1
Nicolaiew	21	1	77·5 = 8658	8000	6·8	6·3
Shide	23	3	86·5 = 9601	8700	7·0	6·3
Rocca di Papa	44	0	89·0 = 9879	8904	3·7	3·3
Catania	46	43	90·0 = 9990	8993	3·5	3·2
Rome	49	0	89·0 = 9879	8910	3·3	3·0

No. 84, February 7, 1897. (B.A. Report, 1897.)

	H.	M.	S.	
Shide	23	54	50	(Corrected)
Potsdam	23	52	0	

No. 85, February 13, 1897. (B.A. Report, 1897.)

	H.	M.	S.
Shide	2	8	11
Potsdam	2	5	0
Rome	2	5	50
Nicolaiew	2	6	1
Edinburgh	2	3	12
Strassburg	2	31	54

Not recorded at Catania, Ischia, and Rocca di Papa.

No. 86, February 13, 1897. (B.A. Report, 1897.)

	H.	M.	S.		M.	S.
Shide	15	23	36	Duration	9	20
Potsdam	15	18	0			

No. 87, February 15, 1897. (B.A. Report, 1897.)

	H.	M.	S.
Nicolaiew	22	12	0
Edinburgh	22	17	0
Potsdam	22	20	0

At Shide on the night of the 15th–16th there were intermittent switchings of the boom.

February 19, 1897.

At Shide instrument not working.

	H.	M.	S.	
Padua	20	51	23	
Verona	20	58	0	Pendulum (Vicentini)
Rome	20	59	50	
Ischia	21	1	25	Period reached, 22·6 secs.
Catania	21	5	25	N.E.–S.W. component. Period reached, 32 secs.
,,	21	6	42	S.E.–N.W.
Rocca di Papa	21	11	0	

	H.	M.	S	
Pavia	21	42	12	Pendulum, 4½ m. 40 kgs.
Nicolaiew	20	52	1	
Potsdam	21	2	0	(about)
Strassburg	21	11	39	S.W.-N.E. component
„	22	25	0	E.-W.
Edinburgh	21	30	0	
Japan	20	41	0	Not recorded in Tokio

No. 88, February 20, 1897. (B.A. Report, 1897.)

	H.	M.	S.		H.	M.	S.
Shide	0	17	47	Four separate maxima ending	1	16	27
Rocca di Papa	23	55	0	On the 19th			
Verona	0	12	0				
Padua	0	15	0				
Ischia	0	15	35	Period reached, 29 secs.			
Rome	0	15	40				
Catania	0	16	47				
Pavia	0	16	30				
Strassburg	0	11	15	S.W.-N.E. pendulum			
Nicolaiew	0	13	1				
Potsdam	0	17	0				
Edinburgh	0	32	0				

At nearly all the above stations several distinct maxima were observed.

No. 91, March 2, 1897. (B.A. Report, 1897.)

	H.	M.	S.	
Shide	21	48	11	
Ischia	21	25	22	E. and W. horizontal pendulum, 12 kgs.
Nicolaiew	21	14	1	
Potsdam	21	22	0	(about)

March 7, 1897.

At Shide record hidden by small tremors.

	H.	M.	S.	
Rocca di Papa	4	51	0	(about)
Tokio	6	24	46	

No. 93, March 16, 1897. (B.A. Report, 1897.)

	H.	M.	S.		M.
Shide	7	36	27	Duration	29
Nicolaiew	6	31	1		

No. 96, March 23, 1897.

On this day the following cables were reported as having been interrupted :—Tenedo-Dardanelles, Malta-Alexandria, Emden-Vigo (Bay of Biscay), and the Aden-Zanzibar. A shock was also reported from Montreal.

A small disturbance was noted at Shide at 4 hrs. 19 mins. 12 secs. P.M., but it is not likely that it was connected with any of the above events.

No. 97, May 5, 1897.

	H.	M.	S.	
Shide	22	44	20	Small
Nicolaiew	22	12	0	With maximum at 22 hrs. 27 mins., which probably corresponds with the Shide record

Not recorded in Italy.

No. 98, May 9, 1897.

It is remarkable that this earthquake, with two maxima and a range of motion of 6 mm., does not appear to have been recorded in Europe. I should be inclined to place its origin west of Great Britain.

No. 99, May 13, 1897.

	H.	M.	S.	
Shide	12	16	24	Moderate
Nicolaiew	12	2	0	Very large

Apparently not recorded in Italy. It most likely originated to the east of Russia (see No. 97).

No. 100, May 23, 1897.

In Tokio, on the above date, a long, slow earthquake was felt at 12 hrs. 23 mins. G.M.T. In Hakodate and Sendai the times given are 12 hrs. 20 mins. and 12 hrs. The time records render it probable that the origin was nearer to Sendai than to the other places; whilst the character of the motion recorded in Tokio and Hakodate makes it probable that the focus of the disturbance would be 200 or 300 miles from those places.

With this assumption the time at the origin, which is likely to be in the Tuscarora Deep, would be about 2 mins. 30 secs. earlier than the Tokio record. The time registers are therefore as follows:—

	H.	M.	S.		°	M.	S.
Time of origin . .	12	20	30				
Nicolaiew . . .	12	48	0	Time to travel	76	27	30
Ischia . . .	13	7	9	,, ,, ,,	89	36	39
Shide . . .	13	15	20	,, ,, ,,	86	54	50
Rocca di Papa . .	13	17	10	,, ,, ,,	89	56	40
Catania . . .	13	20	6	,, ,, ,,	91	59	36

It will be observed that the times taken to travel from the origin, with one exception, increase with the distance of the same to the four observing stations.

From the magnitude of these intervals it is not unlikely that only the maxima phases of motion have been recorded, the preliminary tremors having been so small that they are not shown upon the seismograms.

Velocity Table.

—	Arc	Chord	Velocity in km. per sec. on	
			Arc	Chord
Nicolaiew	76° = 8436 km.	7829 km.	5·1	4·7
Ischia	89° = 9879 ,,	8910 ,,	4·5	4
Shide	86° = 9546 ,,	8668 ,,	2·8	2·6
Rocca di Papa . . .	89° = 9879 ,,	8910 ,,	2·9	2·6
Catania	91° = 10101 ,,	9069 ,,	2·8	2·5

No. 101, May 24, 1897.

	H.	M.	S.	
Nicolaiew (23rd)	23	57	0	Large
Shide.	0	18	59	Moderate
Catania	0	51	46	Small

Also recorded at other stations in Italy.

No. 104, June 3, 1897.

	H.	M.	S.
Catania	9	53	42
Rocca di Papa	9	54	30
Shide	9	57	18
Edinburgh	10	57	0

Nicolaiew not working. Also recorded at other stations in Italy. At Shide there are three maxima phases of movement.

No. 105, June 12, 1897.

This earthquake is one which created so much destruction in Assam that it is intimated, in order to repair roads and buildings of the Public Works Department only, more than thirty-five lakhs of rupees will be required. The total cost of the earthquake is probably many times this sum. To meet the expenditure for the restoration of roads, &c., application has been made for a grant from the Imperial revenues, and we have here an illustration, which is repeated yearly, of the manner in which an earthquake in a distant country may affect directly or indirectly the finances of people in this country. To mitigate the effects of these disasters it is necessary that the ordinary practice of the engineer and builder should be modified, and to this end I am glad to say that this Association has lent support by the publication of several reports bearing upon construction in earthquake countries. The more important of these were issued in 1889 and 1891, and the substance of them has been most carefully considered in connection with the reconstruction of railways and other works now in progress in North-eastern India.

This earthquake, which had its origin in a well-known seismic district, is probably the most severe and disastrous which, during historical times, has been experienced in this region. One evidence of this is the snapping and overturning of a number of ancient monoliths in the Khási Hills. J. C. Arbuthnott, Deputy Commissioner of this district, who describes these stones, says :—'It would possibly give people in England an idea of the severity of the shock were the Druidical stones at Stonehenge and Stennis, in Orkney, similarly overthrown or broken in two.' Similar evidence is found in the destruction of a stone bridge in the Kámrúp district of very great antiquity.

Records.—In the Isle of Wight, strange to say, the movements of the ground commenced whilst the photographic film was being renewed, an operation that only happens once a week. The time record, therefore, only refers to maxima phases of motion and those which followed.

The greatest range of motion was 15 mm., corresponding to a change in slope of about five seconds.

A horizontal pendulum recording N.-S. motion on smoked paper indicated a maximum range of motion of 10 mm. and a period of 15 seconds. The following are the time records :—

	H.	M.	S.	
Shide	11	29	10	Max. The preliminary tremors exceed 10 minutes; therefore the commencement may have been 11 hrs. 19 mins.
Catania	11	17	22	
Rocca di Papa	11	18	0	
Edinburgh	11	18	0	
Strassburg	11	18	32	
Batavia	11	16	40	By electrometer disturbance.

Velocity of Propagation :

Time at origin, 11 hrs. 5 mins. 1 sec.

		M.	S.	Velocity on arc. Km.	Velocity on chord. Km.
Time to reach Catania . .	64°	12	21	9·5	9·0
Rocca di Papa	65°	13	59	8·6	8·1
Edinburgh .	71°	13	59	9·3	8·8
Strassburg .	66°	13	31	9·0	8·5
Shide .	72°	14	59	8·8	8·2

The maximum angular tilting, as indicated on the photographic film, would be about five seconds of arc.

Since writing the above several papers bearing on this earthquake have been received. From one, by Dr. G. Agamennone,[1] I have combined two tables giving the velocities of propagation on arcs of the preliminary tremors (P.T.s) and the long waves (L.W.s), and added notes respecting the character of the instruments yielding the records on which these determinations were made.

Distance from Epicentre Km.	Observing Station	Time G.M.T. of P.T.s	Velocity of P.T.s. Kms. per sec.	Velocity of L.W.s. Kms. per sec.	Instrument H.P. = Horizontal Pendulum
		H. M. S. 11 4 6 or			
400	Calcutta . .	„ 7 0	— —	— —	—
5980	Petersburg .	„ 17 0	8·0 or 9·3	2·59 or 2·78	H.P. photographic
7020	Potsdam . .	„ 17 0	8·9 „ 11·0	— —	H.P. photographic
7150	Catania . .	„ 17 4	8·8 „ 10·8	2·51 „ 2·65	Long pendulum writing
7150	Portici . .	„ 17 9	8·5 „ 10·3	2·55 „ 2·69	—
7170	Mineo . .	„ 16 0	9·9 „ 12·5	— —	—
7170	Ischia . .	„ 17 2	9·0 „ 11·1	2·63 „ 2·78	H.P. writing
7220	Spinea . .	„ 18 6	8·1 „ 9·8	— —	—
7240	Padua . .	„ 17 0	9·2 , 11·4	2·66 „ 2·81	Pendulum writing
7250	Velletri . .	„ 17 0	9·2 „ 11·4	— —	—
7250	Rocca di Papa .	„ 17 5	8·9 „ 10·9	2·66 „ 2·82	H.P. writing
7260	Rome . .	„ 17 1	9·2 „ 11·3	2·67 „ 2·82	Long pendulum writing
7310	Florence . .	„ 18 0	8·6 „ 10·5	— —	—
7330	Wilhelmshaven.	„ 18 9	8·1 „ 9·7	2·52 „ 2·66	H.P. photographic
7390	Livorno . .	„ 17 0	9·4 „ 11·6	— —	—
7440	Pavia . .	„ 18 2	8·6 „ 10·5	2·73 „ 2·90	—
7560	Utrecht . .	„ 17 0	9·6 „ 11·9	2·37 „ 2·49	Magnetometer
7700	Grenoble . .	„ 19 1	8·4 „ 10·1	— —	—
7840	Paris . .	„ 27 6	5·4 „ 6·0	— —	Magnetometer
7970	Edinburgh .	„ 18 0	9·4 „ 11·5	2·78 „ 2·93	Bifilar pendulum photographic
		Mean	8·3 or 10·6	2·61 or 2·76	

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[1] *Rend. della R. Accad. dei Lincei*, vol. vii. 1889, pp. 265–271.

It is worthy of note that we have here instances where higher velocities have been obtained from the records of instruments with frictional writing indices than from those where the records have been photographic, from which it must be inferred that the former indicated earlier phases of motion than the latter.

At Rome the long waves had a period of 10 seconds and a maximum amplitude of 12″. The complete length of these waves, as computed from the above data, would be 54 kms., and the height of their crests about half a metre.

When in Italy (see last section of this report) I saw the original seismograms of this earthquake at nearly all the stations I visited.

The preliminary tremors and the greater portion of the succeeding heavy motion, as given by two different instruments, are reproduced (figs. 1, 2 and 3) from the 'Bollettino della Società Sismologica Italiana,' vol. iii. No. 9. They are appended to a paper by Dr. Cancani, describing his horizontal pendulums and the Assam earthquake. The upper figures show the E.–W. and the N.–S. motion as recorded by the large horizontal pendulums (for a description of which see p. 265). The lower figure gives the corresponding motion, as obtained from an ordinary pendulum of 250 kgs. and 15 m. in length, the movements of which are multiplied 12·5 times. The original diagrams are about two-and-a-half times greater than the present reproduction.

The horizontal pendulums when writing have a complete period of 22 seconds. With the Indian earthquake the maximum range of motion was for the N.–S. component 5·5 cm., and for the E.–W. component 4 cm.

The maximum change in the vertical for the N.–S. component was 13″. The 15 m. pendulum showed a change of 12″, whilst with a third instrument, a simple pendulum, 7 m. in length, it was 10″. For the large waves the complete period was 18 seconds. For these waves, with a velocity of 2·7 kms. per sec., their length becomes 48·6 kms.

If l=length of wave, and a=the maximum angle of tilting, then height of a wave $= \frac{l}{2\pi} \tan a = 45$ cm.

No. 106, June 12, 1897.

	H.	M.	S.	
Shide	19	53	19	Duration 10 mins.
Strassburg . . .	19	23	27	to 8 hrs. 35 min. 7 secs. with maximum at 7 hrs. 51 mins. 33 secs. and 8 hrs. 0 min. 31 secs.

Not recorded in Italy or Russia.

No. 107, June 13, 1897.

	H.	M.	S.		M.
Shide	7	39	33	Duration	7
Strassburg	7	28	55		

Not recorded in Italy or Russia.

No. 112, June 24, 1897.

A disturbance was recorded in Ischia, Padua, and Rome, but it commenced about 20 hrs. 30 mins., and not at 19 hrs. 34 mins. 53 secs., as noted at Shide.

FIG. 1.—Rocca di Papa. Pendolo orizzontale E.-W. Terremoto delle Indie, Provincia di Assam e Bengal, 12 Giugno, 1897.

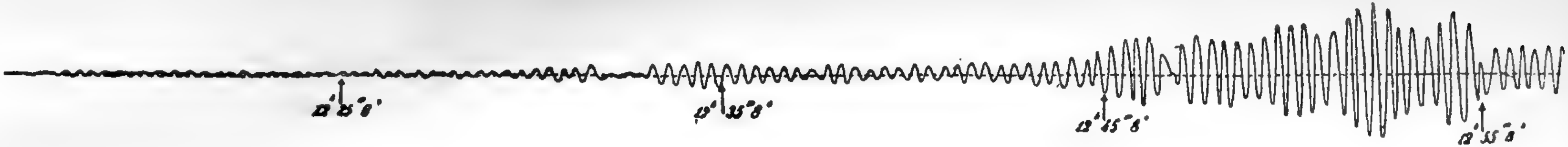


FIG. 2.—Terremoto delle Indie. Rocca di Papa, 12 Giugno, 1897. Pendolo orizzontale N.-S.

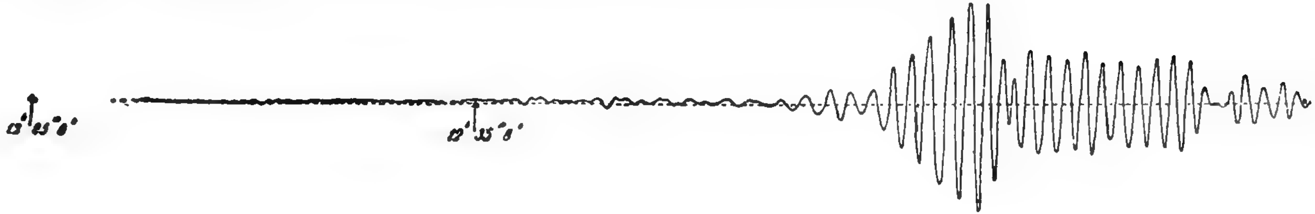
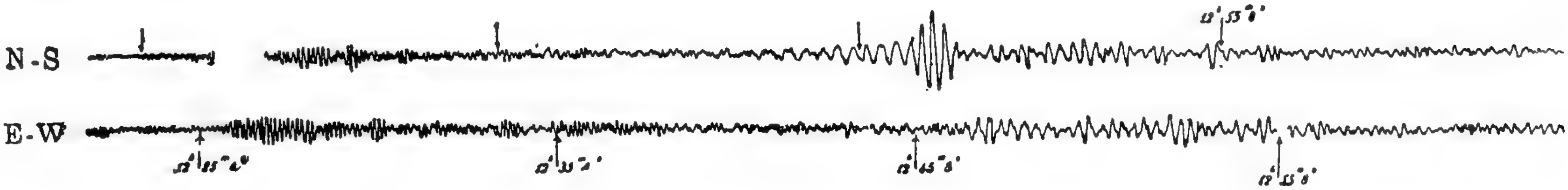


FIG. 3.—Rocca di Papa. Sismometrografo di 15m. Terremoto delle Indie, Prov. di Assam e Bengal. 12 Giugno, 1897. (Adolfo Cancani.)



No. 113, June 30, 1897.

	H.	M.	S.
Shide	4	39	33
Nicolaiew	3	50	0

Not recorded in Italy.

No. 114, June 30, 1897.

	H.	M.	S.
Shide	15	0	2
In Italy about	14	50	0

Origin Epirus.

No. 115, July 17, 1897.

	H.	M.	S.
Shide	7	57	9
Nicolaiew	7	48	0

Not recorded in Italy.

No. 116, July 21, 1897.

	H.	M.	S.		M.	S.
Shide	13	33	32	Preliminary tremors	7	0
Nicolaiew	13	43	0	,, ,,	4	0
Catania	13	39	4	,, ,,	1	23
Rocca di Papa	13	50	0 (maximum)			
Edinburgh	13	40	0			

Also noted at other stations in Italy.

No. 117, July 22, 1897.

Origin Japan:

	H.	M.	S.	
Shide *before*	11	20	0	
Rocca di Papa	11	26	0 (maximum)	
Catania	9	4	58 (exact commencement lost)	
Nicolaiew	9	52	0	
Tokio	9	31	44	Duration 4 mins. 34 secs. Slow movement.

No. 118, August 2, 1897.

	H.	M.	S.	
Shide	15	46	39	All small, and it is likely that the records refer to different shocks.
Catania	15	0	17	
Nicolaiew	15	29	0	

No. 119, August 5, 1897.

This earthquake was felt over the whole of Japan, from Nemuro, in the north-east, to Nagasaki, more than 1,000 geographical miles distant, in the south-west. The following notes taken from the 'Japan Weekly Mail' of Saturday, August 7, give the times at which movements were observed at different towns lying between the above-mentioned places. These times are expressed as Japan mean time, which is exactly nine hours in advance of Greenwich mean time.

The earthquake of Thursday morning was of very long duration, but fortunately, owing to its gentleness, no damage was done. Starting at 9 hrs. 11 mins. 56 secs. A.M., the motion continued for 7 mins. 59 secs., the vibrations moving from E. to W. Four minor shocks were felt at 9.23, 10, and 11.31 o'clock the same morning.

Hakone, 9 A.M. (August 5).

A strong earthquake was felt here this morning at about 9.20 o'clock It lasted for several minutes, but was quite regular (horizontal) in its movement. The Japanese say that they seldom have such a long or strong earthquake here, and they rushed out of their houses very quickly.

Shizuoka (August 5).

A slight earthquake was felt here at 9.20 A.M.

Sendai (August 5).

A strong earthquake occurred here this morning at 9 o'clock.

Mito (August 5).

A strong gale swept over the locality last night, and this morning a sharp earthquake was felt here.

Mayebashi (August 5).

An earthquake occurred here this morning at half-past 9 o'clock.

Uyeda, Shinshu (August 5).

An earthquake was felt here this morning at half-past 9 o'clock.

The earthquake is also reported from :—

Gifu, 7.57 A.M., slight.
Nagasaki, 8.06 A.M., slight.
Kumagaya, 9.07 A.M., strong.
Ishinomaki, 9.10 A.M., strong.
Mito, 9.10 A.M., strong.
Aomori, 9.11 A.M., strong.
Yamagata, 9.11 A.M., strong.
Mayebashi, 9.11 A.M., strong.
Niigata, 9.12 A.M., strong.
Kofu, 9.12 A.M., strong.
Fukushima, 9.10 A.M., feeble.
Nagano, 9.11 A.M., feeble.
Gifu, 9.11 A.M., feeble.
Utsunomiya, 9.12 A.M., feeble.
Tokio, 9.12 A.M., feeble.
Yokosuka, 9.12 A.M., feeble.
Nagoya, 9.13 A.M., feeble.
Akita, 9.20 A.M., feeble.
Choshi, 9.12 A.M., slight.
Numazu, 9.12 A.M., slight.
Nemuro, 9.12 A.M., slight.
Kushiro, 9.13 A.M., slight.
Hachiki, 9.15 A.M., slight.

By reference to the catalogue of earthquakes recorded at the Central Meteorological Observatory in Tokio, p. 190 (Nos. 1901 to 1908), it will be seen that on the 5th the first disturbance was followed by seven smaller disturbances.

From these reports, and from private correspondence with Japan, we learn that the movements were slow. This means that the period of the earth waves would be about three seconds. This being so, experience teaches us that places like Tokio were at a distance of 200 or 300 miles from the origin of the disturbance.

The fact that movements commenced at and near to Tokio at about the same time they commenced at and near to Nemuro, whilst at Ishinomaki, Mito, Aomori, Yamagata, and other places lying between Tokio and Nemuro, movements commenced one or two minutes earlier, leads to the conclusion that the origin was off the east coast of Japan.

From the time observations generally, the locus sought for may be placed near to the centre of a circle which would approximately pass through Tokio, Niigata, and Nemuro. This would lie about 150 miles east of Sendai, at a depth of 4,000 fathoms, exactly at the bottom of the Nippon slope of the Tuscarora Deep. This is practically the same origin as that given for the shock of June 15, 1896,[1] as it is for many other disturbances which have shaken the whole of the Japanese islands. Facts to be noticed about this particular group of earthquakes are that they are the largest, that they originate along the base of the steepest slope, and that it is only occasionally that they are accompanied by sea waves. The disturbance of June 15, 1896, was accompanied by waves which resulted in the loss of nearly 30,000 lives, whilst the shaking of the ground was barely perceptible at Tokio. The earthquake about which I now write as a producer of earth waves which could be felt was much more marked than that of June 15, and yet sea waves were not recorded. The inference is that the earthquake of August 5 was not accompanied by any marked displacement of large bodies of material at the bottom of the ocean, and its origin was practically beneath the sub-oceanic crust. It is therefore possible that we have in the Tuscarora earthquakes examples of disturbances due to accelerations in the secular flow of a quasi-rigid subterranean material under the influence of continental load. If this is the case we should expect to find records of local magnetic perturbation.

Velocity of Propagation of Earth Waves.

Assuming the origin of the earthquake to have been 250 geographical miles to the north-east of Tokio, and the wave to have been propagated to that place at a rate of about 8,000 feet per second, then the time at which the earthquake originated in G.M.T. was August 5, 9 mins. 23 secs.

G.M.T.—Times at which Preliminary Tremors commenced in Europe.

	H. M. S.		M. S.
Shide . . .	. 0 22 35	Time to travel . . .	. 13 12
Rocca di Papa .	. 0 32 40	,, ,, . . .	. 23 17
Catania . . .	. 0 24 35	,, ,, . . .	. 15 12
Nicolaiew . . .	. 0 17 0	,, ,, . . .	. 7 37
Edinburgh . . .	. 1 2 30	,, ,, (Large waves?)	53 7

Apparent Velocity of Preliminary Tremors.

—	Distance		Velocity in km. per sec.	
	On Arc	On Chord	On Arc	On Chord
Nicolaiew	76° = 8436 km	7829	18?	17?
Shide	86° = 9546 ,,	8668	11	10
Rocca di Papa . . .	89° = 9879 ,,	8910	7	6·3
Catania	91° = 10101 ,,	9069	11	9·9

No. 120, August 16, 1897.

	H.	M.	S.	
Shide	8	6	29	
Italy about . . .	8	15	0	at Catania, Ischia, Rome, Rocca di Papa.
Tokio	7	53	33	Duration 3 mins. Slow movement.

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[1] Also see *British Association Report*, 1896, p. 153.

No. 122, August 26, 1897.

	H.	M.	S.
Shide	17	1	41
Nicolaiew	16	32	0
Rocca di Papa	14	46	30
Tokio	16	8	46

No. 123, August 26, 1897.

	H.	M.	S.
Shide	21	40	30
Nicolaiew	21	40	0

And at several places in Italy.

Tokio	21	19	20

No. 124, August 26, 1897.

	H.	M.	S.
Shide	22	13	14
Rocca di Papa	22	8	30

And other stations in Italy.

No. 131, September 17, 1897.

	H.	M.	S.	
Shide	15	59	58	Preliminary tremors.
Catania	15	15	50	Small
Edinburgh	15	55	0	
Nicolaiew	15	40	0	
Rocca di Papa	15	50	0	

And other Italian stations.

Origin probably Tashkent.

No. 132, September 17, 1897.

	H.	M.	S.		M.
Shide	17	59	58	Preliminary tremors.	8
Edinburgh	18	2	0		
Nicolaiew	18	0	0	Details lost	
Rocca di Papa	17	48	0		

And other Italian stations.

The similarity of the Shide seismograms for Nos. 131 and 132 suggests that they originated at or near the same place.

No. 133, September 20, 1897.

	H.	M.	S.		M.
Shide	19	24	47	Large. Preliminary tremors.	40
Edinburgh	19	56	0		
Catania	19	25	2	Small	
Rocca di Papa	19	25	0		
Nicolaiew	19	23	30	Very large	

Also at other stations in Italy.

	H.	M.	S.	
Batavia	19	14	20	by disturbance of an electrometer

No. 134, September 21, 1897.

	H.	M.	S.		M.
Shide	5	28	51	Large. Preliminary tremors.	43
Edinburgh	6	7	30		
Catania	5	29	32	Small	
Rocca di Papa	5	32	8		
Nicolaiew	4	57	0	Very large	

Also at other Italian stations.

The above earthquake evidently refers to one of two shocks which were felt in Sandakan, on the north coast of Borneo, at 1.10 P.M. local time (about 5.20 A.M. G.M.T.) on September 21. It was sufficiently severe to crack a house and stop the town clock.

These and other shocks accompanied the throwing up of a volcanic island in E.L. 115° and N.L. 5° 14′, about which on October 25 the 'Times' writes as follows :—

'A NEW VOLCANIC ISLAND.—The 'Straits Times' of September 29 states that, according to telegraphic advices from British North Borneo, an earthquake was felt at Kudat on September 21, as also a slight tremor at several places along the coast. About the same time a new island was thrown up from the sea between Mempakul and Lambeidan, 50 yards from the mainland, opposite Labuan. The island is of clay and rocks, and measures 200 yards long by 150 yards broad and 60 feet high. The island appears to be increasing in size, and emits inflammable gas in several places, with a strong smell of petroleum gas. The earthquake was not felt at Labuan.'

Comparing this disturbance 134 with 133, both which are large at Shide and Nicolaiew but small in Italy, we have an example of earthquakes apparently from the same origin, and as measured by the distance to which they propagated their vibrations of equal intensity, but which had very different effects locally. The former only slightly disturbed a magnetograph in Batavia, 13° or 1,400 kms. distant, whilst the second created marked disturbances in such instruments at Batavia and other places, p. 243. Also the second was felt severely in Kudat and Sandakan (but not at Labuan), and is reported in the newspapers, whilst the first is passed without notice.

The similarity of the Shide seismograms for 133 and 134 also suggests that these shocks originated at or near the same locality.

No. 135, September 21, 1897.

	H.	M.	S.		H.	M.	S.
Shide	11	36	44	to	13	20	20

About 13 hours in Central Italy there was a violent earthquake, which was recorded at all the observatories in Italy. It is hardly likely that this is represented by the latter portion of the slight disturbances at Shide.

No. 138, October 2, 1897.

	H.	M.	S.			H.	M.	S.
Shide .	13	36	39	Moderate	Duration .	0	27	0
Catania .	13	31	51		„ .	0	32	11
Nicolaiew .	12	56	30	Very large	„ .	1	36	0

Also at Rome.

Tokio .	12	45	19	„ „	„ .	0	3	25 by seismograph

No. 139, October 3, 1897.

	H.	M.	S.	
Shide	15	7	9	
Edinburgh	14	58	0	Slight tilt to N.

No. 140, October 19, 1897.

	H.	M.	S.		M.		H.	M.	S.
Shide . .	0	6	52	Preliminary tremors.	41	Duration	2	30	0
Edinburgh .	0	28	0			,,	0	32	0
Catania . .	0	6	36	Small		,,	0	52	42
Rocca di Papa .	0	5	30			,,	1	9	30
Nicolaiew .	0	13	0	Very large. P.T.s	7	,,	3	1	0

Also at Rome and Ischia.

No. 141, October 20, 1897.

	H.	M.	S.		M.		H.	M	S.
Shide . .	14	43	29	Preliminary tremors.	42	Duration	2	33	0
Edinburgh .	15	20	0			,,	0	13	0
Catania . .	14	49	26	Small					
Rocca di Papa .	15	0	0			,,	2	0	0
Nicolaiew .	14	49	0	Very large. P.T.s	11	,,	3	4	0

Also at Rome and Ischia.

The similarity of the Isle of Wight seismograms for Nos. 140 and 141 together, that in each case the Nicolaiew instrument commenced its records 6 or 7 minutes after the Isle of Wight, indicate that these earthquakes had a similar origin.

No. 142, October 23, 1897.

	H.	M.	S.	
Shide .	3	19	0	
At about .	3	15	0	a disturbance was noted at Catania, Ischia, and Rome.

No. 146, November 14, 1897.

	H.	M.	S.		M.
Shide	14	53	35	Duration	22
Edinburgh	15	29	0	Tilt to N.	

Not recorded in Europe.

No. 152, November 25, 1897.

	H.	M.	S.		H.	M.
Shide	10	1	48	Duration	2	0
Catania	10	19	3	,,	1	23

No. 153, December 11, 1897.

	H.	M.	S.			H.	M.	S.
Shide . .	10	4	31	Small	Duration .	0	45	0
Catania . .	9	51	28	P.T.s 14h. 21m. small	,, .	1	20	54
Nicolaiew .	10	9	0	Moderate	,, .	1	10	0
Tokio . .	9	40	49	Slight				

No. 155, December 17, 1897.

	H.	M.	S.		H.	M.	S.	
Shide	18	30	0	Up to Dec. 18	10	30	0	Slight

Italy, a strong shock, Dec. 18 about 7.30 A.M.

No. 156, December 28, 1897.

	H.	M.	S.			M.	S.		M.
Shide . .	20	54	21	Moderate.	P.T.s	8	0	Duration .	24
Nicolaiew .	20	53	0	Small				,, .	29
Toronto . .	20	24	37	,,	P.T.s	7	10	,, .	35

It will be observed that we have here the records from three instruments not controlled by the friction of writing pointers, and therefore fairly comparable.

No. 157, December 29, 1897.

	H.	M.	S.		M.	S.		H.	M.	S.
Shide	11	40	48	Large P.T.s	19	49	Duration	1	22	28
Catania	11	29	10				,,	1	30	50
Rocca di Papa	11	56	0				,,	0	27	0
Nicolaiew	11	47	0	Small			,,	2	5	0
Toronto	11	32	29	No preliminary tremors			,,	1	10	0
Port-au-Prince	11	22	7	Near the origin						

Also at other stations in Italy.

In connection with this earthquake Professor R. F. Stupart, of Toronto, sends me the following note taken from the 'U.S. Monthly Weather Review,' January 1898 :—

'*December* 29*th.* 6 hrs. 32 mins. 43 secs. A.M., Port-au-Prince, Hayti, W.I.

'Professor T. Scherer reports as follows :—"A severe earthquake was experienced at Port-au-Prince, lasting 1 minute and 31 seconds. The following are the conclusions to be drawn from the curves traced by the Secchi seismograph at the meteorological observatory of the College of St. Martial :—

'"The entire phenomenon consisted of five consecutive shocks, the total duration of which was 48 seconds, and of a series of feeble movements very perceptible to an attentive observer. The first shock lasted 8 seconds : it began from east-north-east and from west-south-west. The vertical component was quite strong at about the fifth second. The movement immediately began with more force in the horizontal direction and less in the vertical : this lasted 11 seconds, and the direction from which it came was more toward the east. The third shock lasted 3 seconds, and was characterised by a very regular oscillatory movement. The first shock was the strongest, lasted 10 seconds, began from the north-east, and died away in the south-west, with a vertical component that was scarcely appreciable. All the other movements, after the forty-eighth second, were feeble with the same horizontal direction. During all this time the seismic pendulum described ellipses in the sand whose major axes varied from north-east through the south to south-west. The Bertelli microseismometer was for a long time agitated, and finally maintained a north-south direction.

'"The same earthquake was felt in the neighbourhood of Port-au-Prince and with the same features. It seems to have been very violent in the interior on the island of Dominica."'

This earthquake had a submarine origin, and interrupted the Cape Haytien-Puerto Plata and Puerto Plata-Martinique cables, together with the Dominican land lines.

No. 158, December 29, 1897, to January 1, 1898.

During this interval slight tremors were recorded at Shide. In Italy, on December 29, between 11 hrs. 30 mins. and 13 hrs., perturbations were recorded in several observations. On December 31, at about 17 hrs., a slight disturbance at Ischia and Florence was noted.

No. 161, January 24, 1898.

	H.	M.	S.			H.	M.	S.
Shide	23	45	49	Large P.T.s 16 mins.	Duration	0	33	0
Rocca di Papa	23	49	0		,,	0	56	0
Nicolaiew	23	49	30	Very large	,,	0	37	30
Toronto (25th)	0	13	30	P.T.s 13 mins. 30 secs.				

No. 162, January 29, 1898.

	H.	M.	S.			H.	M.	S.
Shide	13	44	8	Small P.T.s 5 mins. 47 secs.	Duration	0	13	1
Catania	14	4	41	Large P.T.s 1 h. 2 m. 19 s.	,,	1	33	51
Rocca di Papa	13	39	0		,,	0	5	0
Nicolaiew	13	33	0	Small	,,	0	19	0

Also at other stations in Italy.

No. 163, January 29, 1898.

	H.	M.	S.			H.	M.	S.
Shide	15	5	25	Large P.T.s 9 mins. 9 secs.	Duration	1	1	0
Edinburgh	15	15	0		,,	0	10	0
Rocca di Papa	15	5	15		,,	0	35	0
Nicolaiew	15	4	0	Very large	,,	0	58	0
Laibach	15	1	7		,,	0	49	0

At Shide the period of the large waves was 10 secs.

The records evidently indicate the severe earthquake in Asia Minor, respecting which London papers published the following Reuter telegram:—

> '*Constantinople*, February 3, 1898.
>
> 'The earthquakes in Asia Minor continued at intervals from Saturday till Monday. At Balikesri, the military prison, two minarets and fifteen houses were totally destroyed, and every house in the town was more or less damaged. Twenty persons were killed and fifty injured.
>
> 'Considerable damage was done also at Bighadidj, Inegeul, and other villages, though with what loss of life is unknown.'

No. 164, February 5, 1898.

	H.	M.	S.		H.	M.	S.	
Shide	8	36	13	to	9	19	28	Record on smoked paper

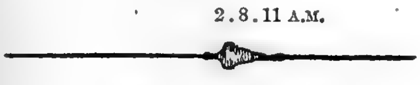
About 9 hrs. perturbations were observed in Catania, Rome, Livorne, &c.

From the preceding lists and notes it appears that between March 23, 1897, and February 16, 1898, 74 earthquakes were recorded at Shide, 38 of which were also recorded in Europe or America.

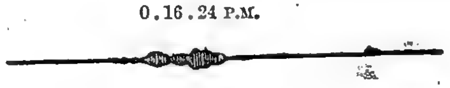
The following are sketches of Seismograms obtained at Shide, Potsdam, and Toronto.

The times given are for the commencement of movements. Other phases of movement may be calculated on the assumption that for

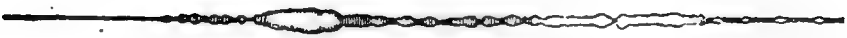
Shide, Nos. 85 to 138, 45 mm.=1 hour; Nos. 140 to 157, 60 mm.=1 hour.
Potsdam, 20 mm.=1 hour.
Toronto, 60 mm.=1 hour.



No. 85.—Shide, Feb. 13, 1897.

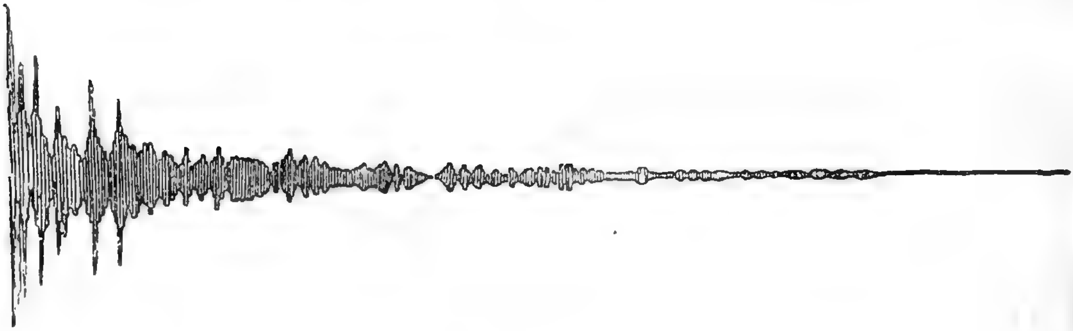


No. 99.—Shide, May 13, 1897.



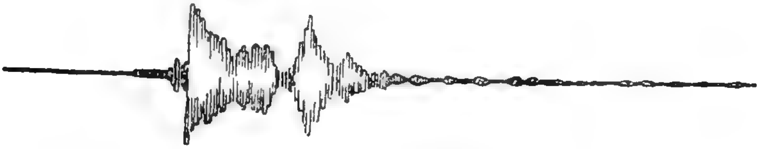
9.57.18 A.M.

No. 104.—Shide, June 3, 1897.



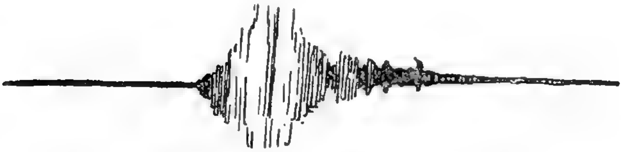
0.32.51 P.M.

No. 105.—Shide, June 12, 1897.

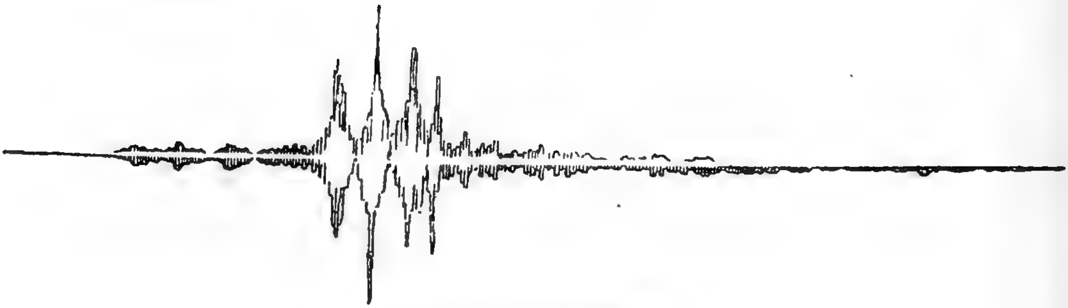


1.33.32 P.M.

No. 116.—Shide, July 21, 1897.

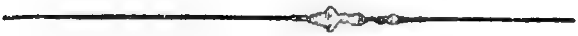


No. 116.—Potsdam.



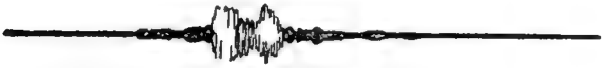
0.22.35 A.M.

No. 19.—Shide, Aug. 5, 1897.

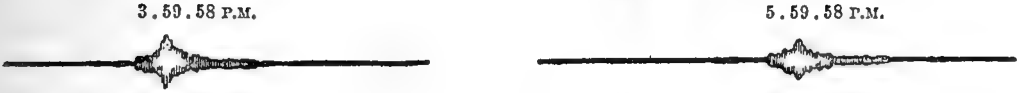


10.13.14 P.M.

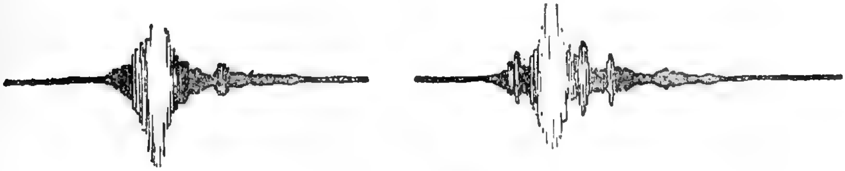
No. 124.—Shide, Aug. 26, 1897.



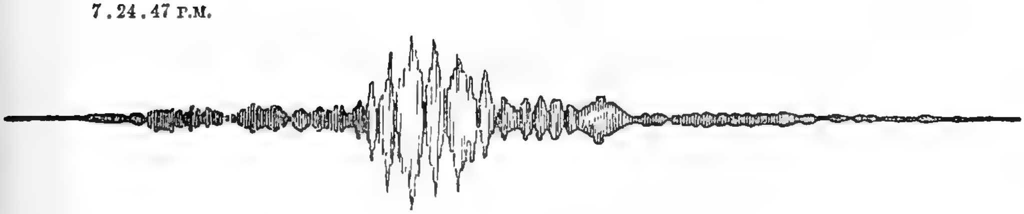
No. 124.—Potsdam.



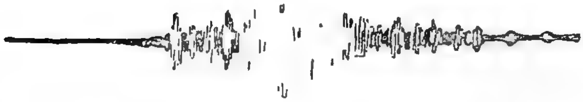
Nos. 131 and 132.—Shide, Sept. 17, 1897.



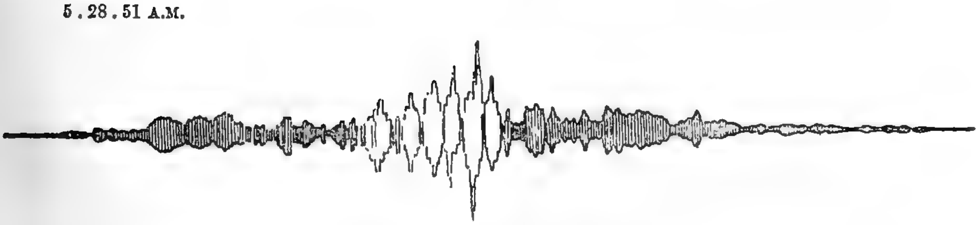
Nos. 131 and 132.—Potsdam.



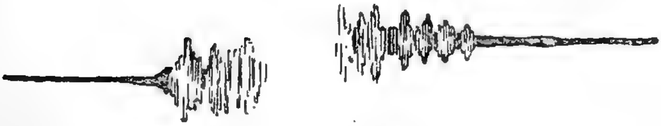
No. 133.—Shide, Sept. 20, 1897.



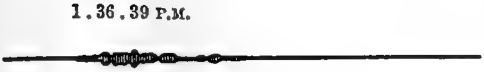
No. 133.—Potsdam.



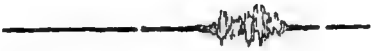
No. 134.—Shide, Sept. 21, 1898.



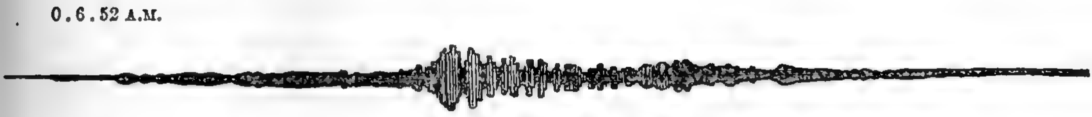
No. 134.—Potsdam.



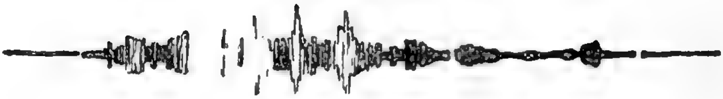
No. 138.—Shide, Oct. 2, 1897.



No. 138.—Potsdam.

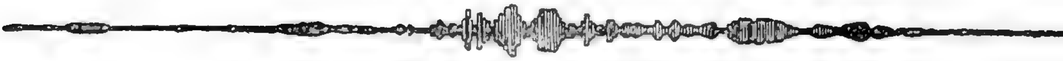


No. 140.—Shide, Oct. 18, 1897.

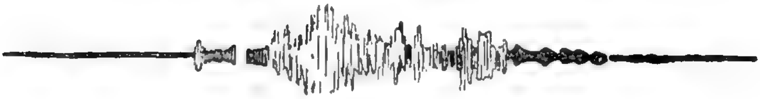


No. 140.—Potsdam.

2.43.29 P.M.

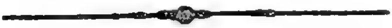


No. 141.—Shide, Oct. 20, 1897.



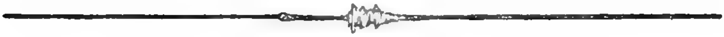
No. 141.—Potsdam.

8.54.21 P.M.



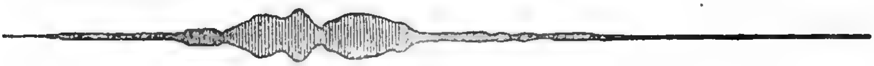
No. 156.—Shide, Dec. 28, 1897.

8.24.39 P.M.



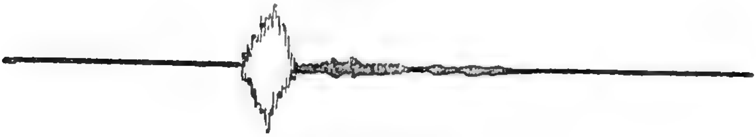
No. 156.—Toronto.

11.40.48 A.M.



No. 157.—Shide, Dec. 29, 1897.

11.32.20 A.M.



No. 157.—Toronto.

V. *On Certain Characteristics of Earthquake Motion.*

1. *The Character of Earth Waves near to their Origin.*

From the feelings of those who reside in earthquake districts, and more definitely from seismograms, we have learned that the movements of the ground constituting an earthquake of moderate intensity, which in an epifocal area may shake badly constructed chimneys and loosen tiles upon a roof, as observed at distances of approximately 20 or 100 miles from its origin, consist of preliminary vibrations, a shock or shocks separated by more or less irregular waves, and a series of concluding vibrations. At distances of from 100 to 200 or 300 miles the preliminary vibrations may not be felt, or even recorded, on an ordinary seismograph, and instead of a shock or shocks we obtain a record of a series of long-period but irregularly recurring waves. These movements give rise to a sensation not unlike that felt upon a floating stage rising and falling upon a swell. The movement of hanging pictures and that of seismographs indicate that an intermittent tilting is taking place. The heavy masses of metal in bracket seismographs, conical pendulums, and other instruments, no longer act as steady points, but swing fitfully with varying amplitudes from side to side, and, rather than giving records of horizontal displacement, they are roughly recording the maximum slopes of the earth waves which tilt the supporting piers.

Beyond the 300-mile limit nothing is felt, and it is seldom that an ordinary seismograph, writing with frictional indices, gives a record. Now and then, where the friction of writing pointers has been exceedingly low, records of unfelt earthquakes have been obtained from ordinary seismographs. It was the magnitude of these diagrams obtained by the writer, coupled with numerous observations made by astronomers on the movement of the bubbles in levels, the tilting of water in ponds, and kindred observations, which enabled him, in 1883, to venture the opinion that with suitable instruments the movement of all large earthquakes might be recorded in any portion of the world (see 'Earthquakes and other Earth Movements,' Int. Sci. Series, pp. 226 and 342). The ample manner in which this has been confirmed is known to all seismologists.

Preliminary Tremors.—The period of these, as recorded on seismographs with frictional indices, has varied between $\frac{1}{5}$ and $\frac{1}{20}$ of a second. Along paths of from 1 to 4 geographical degrees (111 to 444 kms.) the velocity is *apparently* about 2 kms. per second. This, however, is the velocity of the larger waves, which the preliminary tremors most certainly outrace. Strange to say, we know less about the difference in rate of propagation of these small movements and their larger followers over short ranges than we do over long ranges. As a working hypothesis, founded on the interval of time that elapses between the screaming of pheasants and the arrival of sensible motion and the records of seismograms, I anticipate that this interval will be found to be about 10 seconds for about every 100 kms. of travel; that is, if a shock originates at a distance of, say, 200 kms., these preliminary tremors may be noticed 20 seconds before the arrival of pronounced motion. If this is so, then the velocity of propagation for preliminary tremors over short ranges will be about 2·5 kms. per second.

If, for the time being, we accept this factor, then if l is the length of a wave, t its period, and v its velocity, because

$$l=vt$$

with a period of $\frac{1}{20}$ second, the length of a wave is about ·125 km. (410 feet).

Their amplitudes, as shown on seismograms, are exceedingly small, say $\frac{1}{20}$ mm.

Large Waves.—The large waves have periods of from 1 to 2·5 seconds, which, with velocities of 2 kms. per second, would indicate lengths of 2 to 5 kms. (6,560 to 16,400 feet). The maximum amplitudes of these, which represent shocks which will shatter ill-constructed chimneys, lie between 20 and 70 mm.

Concluding Vibrations.—Seismograms clearly show waves having periods of from 3 to 5 seconds, the lengths of which may therefore reach as much as 10 kms. (32,800 feet).

Figures like the above, representing the length of seismic waves, although especially for the large waves we can rely upon the data for velocity and period, must yet be accepted with great caution. For the earthquake of October 28, 1891, as recorded in Tokio, it would appear that seismographs were tilted through an angle of about one-third of a degree, whilst the actual height of the waves was about 10 mm. If these measurements, referred to symmetrically, formed wave-surfaces, the conclusion is that the lengths of the waves did not exceed 20 or 40 feet; the difference between which and, say, 1,600 feet is so great that all confidence in the determination of wave-lengths is apparently destroyed within an epifocal area, or, to be more precise, within five or six miles of an origin. Where waves can be seen rolling down a street, we are here at least certain that the distance from crest to crest of an earth-wave is measured by 10 or 20 feet rather than by hundreds or thousands of feet.

2. *On the Velocity of Propagation of Large Waves.*

From the table on p. 221, where we find the length of arc along which motion may have travelled, the velocity of the preliminary tremors along such a path and the duration of their movements, which is the interval of time by which they outraced the succeeding large waves, it is easy to calculate the velocity with which these waves were propagated. The results of such calculations, together with results obtained from somewhat different data by von Rebeur-Paschwitz and Dr. A. Cancani, are given in the following table:—

Velocities of Large Waves in Km. per sec.

Arc	Along arc	Along chord	Von Rebeur along chord	Cancani along chord
°				
20	2·1	2·1	1 to 2·5	2·5
60	2·8	2·7	—	2·7
80	2·9	2·7	3 to 3·5	—
110	3·3	2·8	—	3·1

3. *On the Character of Earth-waves after having travelled Great Distances.*

The following remarks are based on records of earthquakes obtained at distances from their origin so great that movement of the ground could not be felt, whilst ordinary seismographs failed to indicate any movement of the piers on which they rested. Many of them, for example, refer to seismograms obtained in Europe or England of earthquakes which originated at places so far distant as Japan.

Preliminary Tremors.

Velocity.—In the Report for 1897 (p. 173) a table is given of the highest apparent velocities with which the preliminary tremors of about seventy disturbances have been propagated over or across arcs of great circles on the earth's surface. These arcs have varied in length from about 2° to 156°. The observations on arcs of from 2° to 18° and from 70° to 85° have been fairly numerous. For arcs of intermediate length the observations were only three or four, but inasmuch as these take up their proper position on a curve of velocities, it may be assumed that they are the result of fairly accurate observations. This also applies to the two or three records on wave paths exceeding the 85° limit. In the original diagram ('Report' for 1897, p. 174) those observations which by reference to orginal records are found untrustworthy are surrounded by circles.

The general results arrived at are easily remembered. If it is assumed that motion is propagated *round* the earth, then the velocities over arcs of 20°, 30°, 40° up to about 100°, which have lengths of 2,200, 3,300, 4,000, and 11,100 kilometres, are *about* 2, 3, 4, and 11 kilometres per second. Along wave paths less than 20° the velocity of 2 kilometres per second remains constant. For arcs greater than 100° the velocity apparently increases at a rate somewhat less than the rate at which the length of the arc increases.

With the hypothesis that the vibrations travel along paths approximating to chords through the earth, then the above velocities must be reduced. The actual velocities obtained as mean values from a number of observations are given in columns 9 and 10 of the following table :—

Table showing the Relationship between the Apparent Velocities with which Preliminary Tremors are propagated round or through the Earth, and dimensions of the same, &c. The first four Velocities are derived from Observations. The last two are inferred.[1]

Degrees of Arc	Length of Arc in Kms. 1°=111 Kms.	Length of Chord in Kms. Radius=6,360 Kms.	Diff. in Length of Arc and Chord in Kms.	Max. Depth of Chord in Kms.	Average Depth of Chord in Kms.	$\sqrt{\text{Max.}}$ Depth of Chord	$\sqrt{\text{Average}}$ Depth of Chord	Velocity of P.T.s in Kms. per sec. on Arc	Velocity of P.T.s in Kms. per sec. on Chord	Duration of P.T.s in mins.
20°	2220	2208	12	97	67	9·7	8·18	2·75	2·75	0 to 4
60°	6660	6360	300	853	608	29·20	24·6	6	5·7	20
80°	8880	8175	707	1487	1053	38·8	32·4	8·2	7·5	30 to 34
110°	12210	10419	1791	2712	1977	52	44·4	11	9·3	41 to 43
140°	15540	11952	3588	4197	3149	64·8	56	13·8 ?	9·9	unknown
180°	19980	12720	7260	6360	5097	79·6	71	17·4 ?	11·1	„

It will be observed that the quantities given in the eighth column are approximately four times those in the ninth column.

In questions relating to the direction taken by a wave in passing through the earth, it must be remembered that this may not necessarily be along a chord, but in consequence of refraction follow a path that is curved.

Apparent Duration of Preliminary Tremors.

The following table gives the time intervals by which preliminary tremors have outraced the longer period and larger waves constituting the main portion of various earthquake disturbances. Beneath these time records, inclosed in brackets, the distances of the various observing stations from epifocal areas are given in geographical degrees or kilometres :—

---

[1] See *British Association Report*, 1897, p. 174.

Apparent Duration of Preliminary Tremors. (m = minutes; s = seconds.)

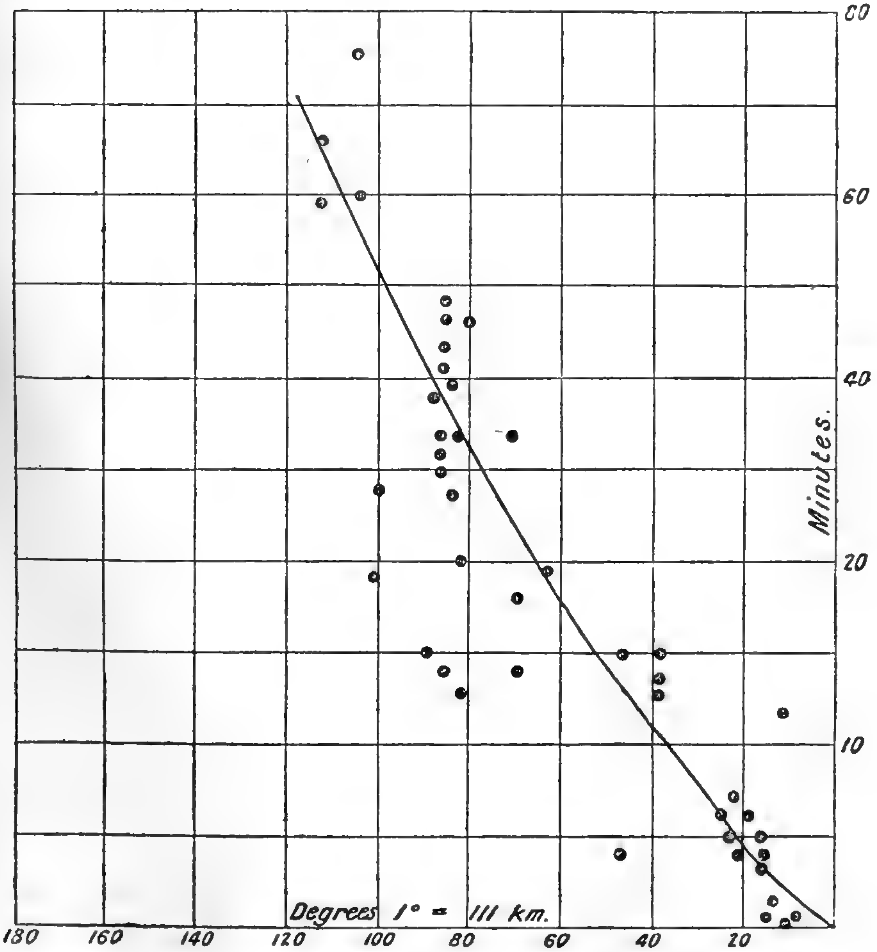
Epicentre	Date	Nicolaiew	Rome	Siena	Charkow	Rocca di Papa	Padua	Ischia	Catania	Strassburg	Shide	Carisbrooke	Potsdam	Wilhelmshaven
S. A., Santiago	Oct. 27, 1894	—	48m. (104°)	40m. (104°)	—	—	—	—	—	—	—	—	—	—
Mexico	Nov. 2, 1894	19m. (102°)	24m.	—	—	—	—	—	—	—	—	—	—	—
Merida, Venezuela	Apr. 28, 1894	—	—	—	15m. (95°)	—	—	—	—	—	—	—	—	—
Japan, N.E. coast	June 15, 1895	—	—	—	—	27m. (86°)	30m. (84°)	32m. (88°)	29m. (88°)	—	—	—	—	—
Japan, Tokio	Oct. 18, 1892	18m. (71°)	—	—	—	—	—	—	—	14m. (86°)	—	—	—	—
”	Nov. 4, 1892	27m. (71°)	—	—	—	—	—	—	—	25m. (86°)	—	—	—	—
Japan, Sakata	Oct. 31, 1896	14m. (71°)	—	—	—	31m. (86°)	—	26m. (85°)	—	13m. (82°)	34m. (83°)	34m. (83°)	—	—
Japan, Tokio	Apr. 17, 1889	—	—	—	—	—	—	—	—	—	—	—	33m. (80°)	21m. (81°)
Philippines	Mar. 16, 1892	24m. (78°)	—	—	—	—	—	—	—	—	—	—	—	—
Luzon	”	21m. (78°·9)	—	—	—	—	—	—	—	—	—	—	—	—
Japan, Tokio	May 11, 1892	33m. (71°·2)	—	—	—	—	—	—	—	27m. ?	—	—	—	—
”	Nov. 4, 1892	27m. (71°)	—	—	—	—	—	—	—	24m.	—	—	—	—
”	Jan. 18, 1895	23m.	—	—	—	—	—	—	—	—	—	—	—	—
Quetta	Dec. 20, 1892	—	—	—	—	—	—	—	—	15m. (45°·7)	—	—	—	—
”	Feb. 13, 1893	—	—	—	—	—	—	—	—	4m. (45°·7)	—	—	—	—
Asia Minor, Amed.	Apr. 16, 1896	—	—	—	—	—	7m.	—	—	—	—	—	—	—
Patras	Aug. 25, 1896	—	—	—	—	—	—	—	—	—	—	—	0m. (15°)	0m.
Thebes	May 23, 1893	0m.	—	—	—	—	—	—	—	0m.	—	—	—	—
Bucharest	Oct. 14, 1892	—	—	—	—	—	—	—	—	0m. (13°)	—	—	—	—
Naples	Jan. 25, 1893	—	—	—	—	—	—	—	—	0m. (9°)	—	—	—	—
Mount Gasgano, Italy	Aug. 10, 1893	—	—	—	—	—	—	—	—	0m. (9°)	—	—	—	—
Cyprus	June 29, 1896	12m. (12°)	4m. (17°)	—	—	4m. (18°)	6m. (19°)	3m. or 7m. (16°)	1m. (15°)	—	—	—	—	—
Iceland	Aug. 26, 1896	7m.	10m. (28°)	—	—	10m.	—	7m. (30°)	14m. (33°)	5m. (21°)	2m. (16°)	—	—	—
Tiflis	Sept. 21, 1896	7m.	4m. (20°)	—	—	5m. (21°)	—	5m. (23°)	6m. (23°)	—	—	—	—	—
Japan	Feb. 19, 1897	10m.	20m.	—	—	26m.	—	21m.	13m. or 19m.	—	—	—	11m.	—
Assam	June 12, 1897	—	—	—	—	—	—	—	—	8m. ?	10m. ?	—	—	—
Japan	Aug. 4, 1897	—	—	—	—	—	—	—	—	—	30m.	—	—	—
N. Borneo	Sept. 20, 1897	—	—	—	—	—	—	—	—	—	40m. & 43m.	—	—	—
Hayti	Dec. 29, 1897	—	—	—	—	—	—	—	—	—	19m. 49s. (64°)	—	—	—

Apparent Duration of Preliminary Tremors.

Epicentre and Date	Nicolaiew	Rome	Siena	Charkow	Rocca di Papa	Padua	Ischia	Catania	Strassburg	Shide	Caris-brooke	Potsdam	Wilhelms-haven	Dorpat
Persian Gulf, Kishim, Jan. 10, 1897	7m.	—	—	—	—	13m.	15m. ?	13m.	—	—	—	—	—	5m.
Umbria, Jan. 19, 1897	—	35s.	—	—	—	—	—	—	—	—	—	—	—	—
Sicily, Calabria, Feb. 11–12, 1897	—	5m.	—	—	—	—	2m.	—	—	—	—	—	—	—
Romana, Apr. 3, 1897	—	10s. (35 km.)	—	—	—	—	—	—	—	—	—	—	—	—
Romana, Apr. 3, 1897	—	10s. (35 km.)	—	—	—	—	—	—	—	—	—	—	—	—

These time intervals and their corresponding distances are shown graphically in the following figure, in which the free curve indicates the general result towards which the observations point :—

FIG. 4.



Intervals by which Preliminary Tremors have outraced Long-period Waves.

Inasmuch as these records have been obtained from different types of instruments which have had different degrees of sensibility, it is clear that they cannot be regarded as individually comparable; but when plotted on squared paper and taken in groups, it is evident that these time intervals increase with the length or depth of the wave-path over or at which a disturbance has travelled. In a few instances, as for example in the case of disturbances originating near Japan, Borneo, and Hayti, which have been recorded by the same or similar instruments in the Isle of Wight and Toronto, such observations are comparable, and they take up expected positions on the average curve of duration drawn through the groups of observations which are not so strictly comparable.

The expectation from this is that this curve will, by future observations, be found to be approximately correct.

An inspection of the same shows that the preliminary tremors up to distances of 12° or 15° only outrace the succeeding waves by intervals seldom reaching a minute. On paths between 20° and 85° the intervals are proportional to the length of the arc, but beyond this range it seems that they may increase at a somewhat higher rate.

Between Europe and Japan, or a distance of 85°, observations have shown that the interval by which the larger waves are outraced varies from 30 to 34 minutes. If we take 32 minutes as an average, then it is easy to compare what should be expected, and what has been observed on ranges lying between 20° and about 100°. This is done in the following table :—

Japan to Shide, 85°		Observation, 32 minutes.
Borneo to Shide, 112°,	42 min. expected.	,, 40 to 43 ,,
Hayti to Shide, 62°,	23 ,, ,,	,, 20 ,,
Hayti to Toronto, 20°,	7 ,, ,,	,, about 4 ,,

Although these observations indicate a working rule, enabling us to determine the distance of an origin from an observing station which, with a knowledge of the surface configuration of our globe and localities where seismic activity is frequent often, are the means of locating an epicentre, the last of the series suggests that the duration of the preliminary tremors are more directly connected with the depth of a wave-path rather than its length, as represented by the arc of a great circle.

Trial, however, shows that the duration of preliminary tremors is not proportional to the length of the chord along which it may be supposed the movements travelled, or to its maximum or average depth.

The table on p. 221, which is derived from fig. 4, shows that the duration of preliminary tremors in minutes is, for the given ranges, nearly equal to the square root of the average depth of the chord expressed in kilometres.

On the Period of Earthquake Waves at Great Distances from their Origin.

All that we know about the period of earthquake waves after they have travelled great distances is derived from the open diagrams of the Italian workers, a few records obtained in the Isle of Wight, and a single but exceedingly valuable record obtained by Dr. F. Omori when in Potsdam. The Italian and Isle of Wight records were obtained from simple or horizontal pendulums writing on smoked paper. The Potsdam record, which refers to an earthquake originating in Japan on February 19, 1897, is photographic, and shows the movements of a pair of von Rebeur pendulums. It has yet to be described.

In the following few examples of records referring to period the following abbreviations are used :—

Pt. = Preliminary tremors, the periods of which are expressed in seconds.
Lw. = Large waves, ,, ,, ,, ,,
P. = Simple pendulum, the length of which is given in metres. These pendulums have multiplying indices.
H.P. = Horizontal pendulums.
G.L. = Geodynamic level (see p. 263, also 'B.A. Report,' 1896, p. 227).

The first name refers to the place at which a given earthquake originated.

1895.	Jan. 18.	Japan.	At Rome P. 16m. gave for Lw. 16·4s.
,,	July 8.	Caspian Sea.	,, Ischia G.L. ,, ,, ,, 22s.
,,	Aug. 9.	E. Italy.	,, Rome P. 16m. ,, ,, ,, 8·8s. and Pt. ·46s.
			,, Rocca di Papa P. 7m. gave for Lw. 7s.
1896.	June 15.	Japan.	,, Padua P. gave for Lw. 40s.
			,, Ischia H.P. (with a natural period of 11s.) gave Pt. 6s. to 12s., and Lw. 20s. to 50s.
			,, Catania gave Pt. 3s., Lw. 15·5s.
			,, Rome P. 8m. gave 21s., P. 16m. 14s. to 20s.
1896.	June 29.	Cyprus.	,, Ischia H.P. gave Pts. 4s., Lw. 10s.
			,, Rocca di Papa P. gave Pt. 4s., Lw. 6s.
,,	Aug. 26.	Iceland.	,, Rome P. 16m. gave Lw. 10s., P. 8m. gave Lw. 10s.
			,, Rocca di Papa P. 15m. gave Lw. 14s., P. 7m. gave Lw. 14s.
			,, Ischia H.P. gave Lw. 18s.
,,	Aug. 31.	Japan.	,, Ischia H.P. gave Lw. 60s. down to 13s.
			,, Rocca di Papa H.P. Lw. 30s. to 14s., P. m gave Lw. 14s., P. 15m. 30s. and 14s.
			,, Rome P. 16m. 8s. to 13s.
			,, Catania P. Lw. 48s. to 72s., Pt. 14s. to 28s.
,,	Sept. 6.	Iceland.	,, Rome P. 16m. gave 11·5s.
			,, Catania Lw. 15s. to 18s.; also 8s. to 16s.
			,, Rocca di Papa P. 15m. gave 14s., H.P. gave 16s., P. 7m. gave 16s.
			,, Ischia H.P. 2 2s. to 17s.
,,	Sept. 22.	Tiflis.	,, Ischia H.P. gave Pt. 2·5s., Lw. 19s.
			,, Rocca di Papa H.P. gave about 17s.
,,	Nov. 1.	Tashkent.	,, Rocca di Papa H.P. gave 18s.
			,, Ischia H.P. 6s. to 25s.
1897.	Jan. 10.	Persian Gulf.	,, Padua P. gave 35s. to 16s., Ischia H.P. gave 25s. to 12s.
			,, Catania P. 25m. gave 6s. to 18s.
,,	June 12.	N.E. India.	,, Shide H.P. gave 15s.

When reading the above records it must be remembered that they refer to the shortest and longest periods which were observed, or to waves with the smallest and largest amplitudes. Near to an origin, after a shock, a disturbance dies out with an increasing period, but at a great distance from an origin the maximum movements which probably correspond to a shock or shocks are those which have the longest period.

Also the fact must not be overlooked that the records refer to seismograms obtained from different instruments, located at different stations, and that it is not certain that comparisons are made between similar phases of motion. The following table is therefore tentative, and when we are in possession of records more strictly comparable it may be subject to considerable alteration :—

Distance from Origin in Degrees	Period in Seconds	
	Preliminary Tremors	Large Waves
0 to 3	·05 to ·2	1 to 4
8 to 10	4 ?	10
23 to 28	2·2	19
35 to 40	6 ?	35
85	3 to 8	20 to 60

All that this table tells us is that both preliminary tremors and large waves exhibit a marked increase in period as they travel, and, whatever the period of a given wave may be in the vicinity of its origin when it has travelled a distance represented by a quarter of the circumference of the earth, its period has increased twentyfold.

VI. *On Certain Disturbances in the Records of Magnetometers and the Occurrence of Earthquakes.* *By* JOHN MILNE.

Although we are aware that the records from certain magnetic observatories rarely, and then only slightly, show that the magnetographs have been disturbed at or about the time of large earthquakes, it is certain that at other observatories these movements of the ground are accompanied and possibly preceded by perturbations as shown upon magnetograms of a very marked character. In some instances these disturbances have evidently resulted from the mechanical shaking to which the magnetic needles have been subjected, but there are other cases where such an explanation is not so clear.

To determine how far these movements may be attributed to mechanical action, whether there is any reason to suppose that certain of them may be the result of magnetic influences, to explain the observation that what are apparently similar earthquakes with like origins are accompanied by different results at the same observatory, and generally with the object of throwing additional light upon a class of phenomena which at present are not well understood, I have collected the materials contained in the following notes.

In addition to sending the list of 'Earthquakes recorded at Shide, 1897–98' (see p. 191), to various earthquake observatories, the same was forwarded to magnetic observatories at the following places: Kew, Stonyhurst, Greenwich, Falmouth, Potsdam, and Bombay. Accompanying the list there was a request that the same might be returned with notes respecting any magnetometer perturbations which might have been noted at about the times of the earthquakes which were more pronounced.

Some time later I drew up a second list of earthquakes which had been recorded in Italy, Germany, and England, the greater number of which had originated at great distances from these countries, and appended to the same a request similar to that attached to the Shide list. On April 5 this was forwarded to magnetic observatories at the following places :—

Pawlowsk (Odessa), Kasan and Tiflis (Russia), Irkutsk (Siberia), Prague, Vienna, and Pola (Austria), Ó-Gyalla (Hungary), Utrecht (Holland), Nice and Perpignan (France), Copenhagen (Denmark), Madrid

(Spain), Coimbra (Portugal), Kew, Greenwich, and Stonyhurst (England), Zi-ka-wei and Hong Kong (China), Manila (Philippine Islands), Batavia (Java), Mauritius, Melbourne (Australia), Loanda (West Africa), Havana (Cuba), Toronto (Canada), Washington (United States), Bombay (India), Tokio (Japan).

Earthquakes recorded in Germany, Italy, and England, many of which originated at great distances from these Countries.

The time employed is Greenwich Mean Time.

No.	Date	Hour	Origin	Magnetometer Disturbances											
				Kew	Utrecht	Copenhagen	Vienna	Pola	Bombay	Potsdam	Wilhelmshaven	Pawlowsk	Mauritius	Zikawei	Greenwich
		H. M.													
	1889.														
1	Apr. 18	5 21 a	Japan .										—	—	—
2	July 11	10 22 p	Quetta .		—				—				—		—
3	,, 28	3 30 p	Japan .										—		
4	,, ,,	6 0 p	,, .											—	—
5	Aug. 25	7 37 p	Greece . .	—									—		—
	1891.														
6	Oct. 27	9 38 p	Japan . .		—								—	—	—
	1892.														
7	Mar. 16	1 22 p	Manila . .										—	—	—
8	,, ,,	5 22 p	,, . .										—		
9	Apr. 19	11 30 a	California .		—										
10	May 12	5 43 a	Japan . .	—	—			—							—
11	Oct. 19	4 21 a	,, . .	—									—	—	—
12	Nov. 4	5 24 p	,, . .	—									—		—
13	,, 27	5 57 p	California .										—		—
14	Dec. 9	1 19 a	Japan . .										—		—
15	,, 20	0 34 a	Quetta . .												—
	1893.														
16	Jan. 28	11 46 p	Italy . .	—	—								—		—
17	,, 31	4 19 a	Zante . .												—
18	Feb. 1	0 39 a	,, . .												
19	,, 6	5 7 p	Japan . .										—	—	—
20	,, ,,	7 4 p	,, . .												—
21	,, 9	6 13 p	Turkey . .	—				—	—				—		—
22	,, ,,	9 40 p	Japan . .						—				—		—
23	,, ,,	11 0 p	,, . .												—
24	,, 13	5 0 p	Quetta . .										—	—	
25	,, 16	5 17 a	Japan . .										—	—	—
26	,, ,,	0 4 p	,, . .		—										—
27	,, 21	7 13 a	,, . .												—
28	,, ,,	2 18 p	,, . .												—
29	,, 22	11 16 p	,, . .												—
30	Mar. 2	11 6 p	Turkey . .	—	—	—							—		—
31	,, 14	6 20 a	Italy . .										—		—
32	,, 20	5 10 p	Zante . .												
33	,, 23	8 43 p	Japan . .		—								—		—
34	Apr. 8	1 51 p	S.W. Germany .	—	—	—	—						—		—
35	,, 17	5 48 a	Zante . .										—		—
36	,, 23	1 32 p	Italy . .		—										
37	,, 29	6 2 p	,, . .										—		

EARTHQUAKES RECORDED IN GERMANY, ITALY, AND ENGLAND—*continued.*

No.	Date	Hour	Origin	Magnetometer Disturbances											
				Kew	Utrecht	Copenhagen	Vienna	Pola	Bombay	Potsdam	Wilhelmshaven	Pawlowsk	Mauritius	Zikawei	Greenwich
38	May 2	9 58 a	„ . .												—
39	„ 18	2 39 p	„ . .										—		—
40	„ 19	1 3 a	„ . .		—										—
41	„ 23	8 38 p	Greece . .	—	—								—		—
42	June 3	4 25 p	Unknown .	—			—						—		
43	„ 7	10 10 p	Italy . .												—
44	„ 11	9 9 p	„ . .										—	—	—
45	„ 13	11 5 a	„ . .												
46	„ 14	6 47 a	Greece . .												
47	July 3	10 5 a	„ . .												—
48	„ 5	11 24 a	Italy . .												
49	„ 10	0 14 p	„ . .												
50	Aug. 2	1 43 a	„ . .		—										
51	„ 4	0 52 a	„ . .												—
52	„ 6	7 42 p	„ . .				—						—	—	—
53	„ 10	9 9 p	„ . .												—
54	„ 14	7 48 p	„ . .					—							—
	1894.														
55	Mar. 22	10 37 a	Japan . .	—	—			—					—	—	—
56	Apr. 20	5 42 p	Greece . .												—
57	„ 27	7 55 p	„ . .		—	—									—
58	„ 29	3 25 a	Venezuela .										—		—
59	June 20	5 45 a	Japan . .										—	—	—
60	July 10	10 30 a	Constantinople .	—	—	—									—
61	„ 12	2 17 p	„ .			—		—							
62	Oct. 7	11 40 a	Japan . .										—	—	—
63	„ 22	9 0 a	„ . .	—	—										—
64	„ 27	9 8 p	Argentina .	—	—								—	—	—
	1895.														
65	Jan. 18	2 37 p	Japan . .					—					—	—	—
66	July 8	10 43 p	Caspian Sea		—	—		—		—	—	—	—	—	—
67	Aug. 9	5 38 p	E. Italy .					—					—	—	—
68	Nov. 13	9 31 p	W. Asia Minor . .										—		—
	1896.														
69	June 15	11 46 a	Japan . .	—	—		—						—		—
70	„ 29	9 2 p	Cyprus . .										—		—
71	Aug. 26	11 22 p	Iceland . .		—					—	—				—
72	„ 31	8 23 a	Japan . .						—		—		—		—
73	Sept. 6	0 2 a	Iceland . .		—				—	—					—
74	„ 14	10 30 a	N.W. Asia Minor .												—
75	„ 22	4 53 a	Tiflis . .							—	—		—		—
76	Nov. 1	5 18 a	Tashkent .		—	—				—	—				—
	1897.														
	Jan. 10	9 18 p	PersianGulf					—					—		
	June 12	11 29 a	N.E. India.	—	—	—			—		—	—	—		
	Aug. 5	0 22 a	Japan . .		—										
	Sept. 20	7 24 p	E. Borneo .										—		
	„ 21	5 28 a	„ .		—			—	—				—		
	Dec. 28	8 54 p	W. Indies .												
	„ 29	11 40 a	„ .										—		

The chief feature in this list is that with one exception it refers to earthquakes of which we know the origin. The exception is No. 42, and it is here included because it refers to an earthquake which probably disturbed the whole of the globe, and had a duration greater than any yet recorded. In Japan I recorded it as having a duration of 5 hrs. 24 mins. In Strassburg it continued 11 or 12 hours.

In the columns for magnetometer disturbances, especially for Kew and Mauritius, it must not be inferred that the marks necessarily indicate anything more than that slight magnetic perturbations have occurred at about the times specified. The Potsdam, Wilhelmshaven, and Pawlowsk records date from 1895.

Further information has been obtained from the earthquake catalogues published from time to time by Professor Pietro Tacchini in the 'Bollettino della Società Sismologica Italiana.'

These records date only from 1895, and refer to Utrecht, Potsdam, Wilhelmshaven, and Pawlowsk.

What has been gathered from these lists, together with that from replies to circulars, more of which may yet be expected, is tabulated in a uniform manner in the following lists :—

0, as, for example, 'Potsdam = 0,' means that the magnetographs at Potsdam were not disturbed.

D means Declinometer or the unifilar record.

H means Horizontal Force record.

V means the Vertical Force, or Lloyd's balance record.

The times are given in hours and minutes G.M.T.

Replies relating to the List on p. 191.
(*Earthquakes recorded at Shide, Isle of Wight*, 1897–98.)

1. *Records from the Kew Observatory, Richmond, Surrey. Superintendent*, Dr. CHARLES CHREE, *F.R.S.*

Dr. Charles Chree, F.R.S., superintendent of the above observatory, tells me that he and Mr. Baker have looked at the curves, chiefly for horizontal force, at the times of the *large* movements in the Shide list, and he points out that near these times—as near any other set of arbitrary times—there are movements of the ordinary magnetic small wave type. Such movements go on for hours, if not for days; and by some the view is held that they are always, or nearly always, existent, and might be seen if we had only delicate enough instruments and an open time scale. When earth movements have affected the trace there is a 'burr,' but such a 'burr' might be equally well caused by an assistant entering the room with keys or a knife in his pocket. In only one case—No. 104, June 3—was there evidence of a movement not due to natural magnetic causes, excepting one on October 20, No. 141, which might more naturally be assigned to human creation. The June 3 movement would pass for an earthquake, but it took place at an hour when there are frequent movements in the building, as absolute meteorological observations are taken then. Traces free from small movements, excepting the vertical force, are rare. On a moderately disturbed day the movements are in dozens, or rather hundreds. In the following list the numbers refer to those on the Shide list, and if these are followed by = 0 this means that at the corresponding dates the magnetometers were not disturbed : 98 = 0. 104. At

10 A.M. a slight movement, apparently not magnetic. 116=0. 119=0. 131=0. 132=0. 133 probably = 0. 134=0. 140=0. 141. At 2.58 P.M. movements probably due to an assistant. 145=0. 157=0. 163. A slight movement, about 2.50 P.M., of a doubtful kind.

Records from the Royal Observatory, Greenwich.

Through the kindness of the Astronomer Royal, the following note relating to the Shide register, p. 191, were drawn up by Mr. Nash :—

Shide No.	Movements noted at Greenwich.
98*	Small movement in H and D at 23h. 30m.
99	„ „ „ about 12h. 20m.
100	„ „ „ at 13h. 15m.
101	Very small movements in H and D.
102	„ „ „ D.
103	Small movements in H and D at 4h. 45m.
104*	Small wave in H and D at 9h. 50m.
105	Very small movement in D at 11h. 45m.
106	Small „ in D at 19h. 55m.
107*	„ wave in H and D at 7h. 30m.
108	„ movement in H at 10h. 55m.
110	„ wave in H at 20h. 15m.
111	„ movement in H at 14h. 15m.
115	Very small fluctuations in H and D.
116*	„ „ movement in D at 15h. 40m.
118*	„ „ „ in D and H, 6h. 10m. to 6h. 45m.
120	„ „ „ in H and D at 21h. 45m.
122	„ „ wave in D.
123	Small decrease in H and D at 15h. 10m.
125*	„ wave in H and D at 1h. 20m.
130	Very small movement in H about 19h. 28m.
131	Small movement in H.
132*	„ wave in H and D at 23h. 50m.
134	„ movement in H and D at 13h. 40m. ±
136	Wave in H and D at 0h. 15m.
137*	Small movement in H at 14h. 40m.
142	„ „ in H and D 3h. 30m.
143	„ wave in D.
144	„ movement in H at 9h. 48m.
147*	Active movements in H and D, commencing a 4h.
155	Small „ in H and D.
156	Very small „ in D.
160	Small „ in H, again in D & H, 17h. 40m. to 17h. 45m.

We have here 33 instances where it is possible that a connection may exist between earthquake movements and the movements of magnetic needles. In the cases marked with an asterisk the movements of the needles preceded those of the ground.

Replies relating to the List on p. 227.

Magnetometer Movements noted at the Kew Observatory, Richmond, Surrey, England. Superintendent, Dr. CHARLES CHREE, *F.R.S.*

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
				1889.	
				H. M.	
1	1	IV.	18	5 21 A.M.	D and H no trace of earthquake. The previous two days were very quiet except for some *small* movements on the 17th—1 to 3 P.M. and 5 to 7 P.M.
2	5	VIII.	25	7 37 P.M.	On D some very small, apparently ordinary, magnetic movements about 7.37. On H small movements—all say on 25th—the largest between 4 and 6 P.M., but no trace of earthquake. The 24th distinctly quiet, but for slow moderate movements of D about 10 P.M.
				1892.	
3	10	V.	12	5 43 A.M.	D trifling movements, but they look magnetic. H shows no trace of earthquake. On the 11th very quiet. H shows lots of small movements, the largest (not big) shortly before midnight.
4	11	X.	19	4 21 A.M.	D and H no earthquake movement. Noon 17th and 10 P.M. on 19th many varied movements. The fastest large change of H on the 18th about 5 and 8 P.M. Sharp change of D on 18th between 5 and 5.30 P.M.
5	12	XI	4	5 24 P.M.	D many small movements, but no certain earthquake. No trace of earthquake on H. Many small disturbances on the 4th up to 4.30 P.M.; pretty sudden commencement on the 4th about 2.29 A.M.
6	14	XII.	9	1 19 A.M.	D and H no trace of earthquake. On the 8th many smallish movements from 8 A.M. to 11 P.M. Largest on D about noon.
				1893.	
7	21	II.	9	6 13 P.M.	Certain small movements might be earthquake effect, but there are several not dissimilar at no great time interval. The 9th, but for many small vibratory movements, was quiet. The 8th was generally quiet. A small slow movement of H at 10.40 to 11.20 P.M.
8	30	III.	2	11 6 P.M.	No trace of earthquake on D. Some movements but apparently magnetic, on H. The 2nd was generally quiet. On the 1st two well-marked movements last 7.20 to 8.30 P.M.
9	31	III.	14	6 20 A.M.	No trace of earthquake on D and H. 13th and 14th, on the whole, quiet; on 13th some slow waves on H between 1.45 and 8 P.M., also on D about 12.30 to 2 P.M. and about 6 P.M.

MAGNETOMETER MOVEMENTS—*continued.*

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
				H. M.	
10	34	IV.	8	1 51 P.M.	No trace of earthquake of E or H. D a little irregular, but nothing special, at 1 51. The 8th and 7th generally quiet, but many small vibrations on D on 7th and early on the 8th.
11	42	VI.	3	4 25 P.M.	Some slight movements, apparently magnetic. The 3rd and 2nd generally quiet. A few *small* movements on D on the 2nd and early on the 3rd.
12	45	VI.	13	11 5 A.M.	No trace of earthquake on H or D. On the 12th H shows a slight hump from 0 to 1 A.M., otherwise very quiet; D shows a lot of very small movements, a noticeably sharp one about 6.15 A.M., and a hump on curve from midnight to 1 A.M.

Magnetometer Movements noted at the Royal Observatory, Greenwich, from 1889 *to* 1896. *Drawn up by* Mr. P. H. COWELL.

[For a more detailed description see the Greenwich volumes.]

No.	No. on List p. 227	Month	Day	Time of Earthquake	Beginning of Magnetometer Disturbances
1889.					
				H. M.	
1	1	IV.	18	5 21 A.M.	Very small, from 17d. 9h. A.M. to 6h. P.M.
2	2	VII.	11	10 22 P.M.	2h. P.M.
3	5	VIII.	25	7 37 P.M.	From noon.
1891.					
4	6	X.	27	9 38 P.M.	,, 4h. 45m. P.M.
1892.					
5	7	III.	16	1 22 P.M.	From 15d. 8h. P.M. to 16d. 3h. A.M.
6	10	IV.	12	5 43 A.M.	Small disturbance from 11d. 11h. 30m. P.M.
7	11	X.	19	4 21 A.M.	Storm from 17d. noon.
8	12	XI.	4	5 24 P.M.	,, ,, 4d. 2h. A.M.
9	13	,,	27	5 57 P.M.	From 26d. 2h. 30m. A.M. to 5h. A.M.
10	14	XII.	9	1 19 A.M.	Disturbance from 8d. 2h. A.M. to midnight.
11	15	,,	20	0 34 A.M.	From 19d. 10h. 30m. P.M.
1893.					
12	16	I.	28	11 46 P.M.	From 0h. 30m. A.M.
13	17	,,	31	4 19 A.M.	,, 1h. 30m. A.M.
14	19	II.	6	5 7 P.M.	Storm from 4d. noon to 6d. noon. Subsequently a large disturbance.
15	20	,,	,,	7 4 P.M.	
16	21	,,	9	6 13 P.M.	From 9d. 6h. P.M.
17	22	,,	,,	9 40 P.M.	
18	23	,,	,,	11 0 P.M.	
19	25	,,	16	5 17 A.M.	Considerable disturbance from 15d. 1h. P.M.
20	26	,,	,,	0 4 P.M.	

MAGNETOMETER MOVEMENTS—*continued.*

No.	No. on List p. 227	Month	Day	Time of Earthquake	Beginning of Magnetometer Disturbances
				H. M.	
21	27	,,	21	7 13 A.M.	Disturbance from 20d. 5h. P.M. to 10h. P.M.
22	28	,,	,,	2 18 P.M.	,, ,, 21d. noon.
23	29	,,	22	11 16 P.M.	Slight ,, ,, 22d. noon — principally at 8 P.M.
24	30	III.	2	11 6 P.M.	From 10h. 30m. P.M.
25	31	,,	14	6 20 A.M.	,, 3h. A.M.
26	33	,,	23	8 43 P.M.	Very small disturbance from 6h. P.M.
27	34	IV.	8	1 51 P.M.	,, ,, ,, ,, 1h. to 10h. A.M.
28	35	,,	17	5 48 A.M.	Disturbances from 16d. 3h. P.M. Small disturbance 17d. 4h. A.M.
29	38	V.	2	9 58 A.M.	A small, sharp disturbance 1d. 10h. P.M.
30	39	,,	18	2 39 P.M.	Disturbance at noon.
31	40	,,	19	13 A.M.	Small at 18d. 8h. P.M., and a smaller at 19d. 1h. A.M.
32	41	,,	23	8 38 P.M.	At 6h. P.M.
33	42	VI.	3	4 25 P.M.	Register interrupted for Visitation Day.
34	43	,,	7	10 10 P.M.	A great disturbance 6d. 9h. P.M. Fluctuations subsequently.
35	44	,,	11	9 9 P.M.	Disturbance from 10d. 7h. P.M.
36	47	VII.	3	10 5 A.M.	Very small disturbance since 2d. 11h. A.M.
37	51	VIII.	4	0 52 A.M.	From 3d. 7h. P.M.
38	52	,,	6	7 42 P.M.	Storm beginning 6d. 4h. A.M.
39	53	,,	10	9 9 P.M.	From 3h. P.M.
40	54	,,	14	7 48 P.M.	Very small disturbance 5h. 30m. P.M.
				1894.	
41	55	III.	22	10 37 A.M.	Storm commences 21d. noon.
42	56	IV.	20	5 42 P.M.	Fluctuations from 5h. A.M.
43	57	,,	27	7 55 P.M.	Slight irregularity at 3h. A.M.
44	58	,,	29	3 25 A.M.	From 1h. A.M.
45	59	VI.	20	5 45 A.M.	Moderate disturbance for some time past. Wave at 4h. A.M.
46	60	VII.	10	10 30 A.M.	From 9d. 8h. P.M.
47	62	X.	7	11 40 A.M.	,, 6h. A.M.
48	63	,,	22	9 0 A.M.	,, 0h. A.M.
49	64	,,	27	9 8 P.M.	,, 5h. P.M.
				1895.	
50	65	I.	18	2 37 P.M.	From 17d. noon.
51	66	VII.	8	10 43 P.M.	,, 6h. A.M. and 1h. P.M.
52	67	VIII.	9	5 38 P.M.	,, 8h. A.M.
53	68	XI.	13	9 31 P.M.	,, 7h. P.M.
				1896.	
54	69	VI.	15	11 46 A.M.	From 14d. 2h. A.M. to 15d. 3h. A.M. Sharp waves 14d. 3h. 30m. to 6h. P.M.
55	70	,,	29	9 2 P.M.	From 3h. P.M. to midnight. Waves 6h. 30m. to 9h. 30m. P.M.
56	71	VIII.	26	11 22 P.M.	Almost continuous from 23d. 2h. P.M. to 25d. 9h. P.M.
57	72	,,	31	8 23 A.M.	From 29d. noon to 30d. noon. Marked at 29d. 4h. P.M.
58	73	IX.	6	0 2 A.M.	From 4d. noon to 5d. 10h. P.M. Marked on 5d. 8h. 30m. to 10h. A.M.

It will be observed that these records, unlike those in the next register for Utrecht, do not refer to 'burr'-like markings produced at the time of earthquakes, but to magnetic movements which have had a considerable duration, and which commenced some hours before the occurrence of the earthquakes to which they are in juxtaposition.

For fourteen earthquakes it will be noticed that there is no corresponding magnetic disturbance, but, singularly enough, at least ten of these earthquakes were small, originating, for example, in Italy, the mechanical movements accompanying which were not recordable even at so short a distance as England. Apparently, therefore, the greater number of perturbations recorded at Greenwich have only preceded very large earthquakes representing internal adjustments of the earth's crust. Something analogous to this will be found in the Zikawei register, p. 245.

Magnetometer Disturbances recorded at the Royal Meteorological Institute of the Netherlands, Utrecht. Director, Dr. M. SNELLEN.

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
1889.					
1	2	VII.	11	H. M. 10 22 P.M.	D 10h. 42m. max. at 10h. 50m., and 11h. 1m. H 10h. 39m., with max. at 10h. 41m., 10h. 52m., 11h. 2m., and 13h. 20m.
1891.					
2	6	X.	27	9 38 P.M.	D 9h. 0m. 8s.; 9h. 28m.; 9h. 44m. 50s.; 10h. 2m.; 10h. 8m.; 10h. 32m. H. = 0.
1892.					
3	9	IV.	19	11 30 A.M.	D and H 11h. 33m.
4	10	V.	12	5 43 A.M.	D and H 7h. 14m.?
1893.					
5	16	I.	28	11 46 P.M.	D 9h. 24m.; 10h. 0m.; 11h. 2m. H 9h. 26m.; 10h. 0m.
6	26	II.	16	0 4 P.M.	D 10h. 46m.; 11h. 34m.; 11h. 56m. H 10h. 48m.; 11h. 24m.; 12h. 4m.
7	30	III.	2	11 6 P.M.	D 11h. 56m. H 11h. 56m.
8	33		23	8 43 P.M.	D 8h. 54m. H not registering
9	34	IV.	8	1 51 P.M.	D 1h. 42m.; 1h. 56m. H 1h. 40m.; 1h. 57m.
10	36		23	1 32 P.M.	D 2h. 40m. H 2h. 40m.
11	38	V.	2	9 58 A.M.	D 9h. 51m.; 9h. 58m. H 9h. 51m.; 9h. 58m.
12	40	—	19	1 3 A.M.	D 1h. 19m. H = 0.
13	41	—	23	8 38 P.M.	D 7h. 36m. H 8h. 20m.
14	50	VIII.	2	1 43 A.M.	Aug. 1, D 11h. 20m. P.M.; 11h. 36m. P.M. H 11h. 36m. P.M.
1894.					
15	55	III.	22	10 37 A.M.	D 10h. 27m.; 19h. 26m., &c. H 10h. 27m.; 11h. 21m., &c.
16	57	IV.	27	7 55 P.M.	D 7h. 57m. H 7h. 57m.
17	59				Not registering
18	60	VII.	10	10 30 A.M.	D 10h. 28m. H 10h. 1m.; 10h. 32m.
19	63	X.	22	9 0 A.M.	D 7h. 51m. H 9h. 0m.
20	64	—	27	9 8 P.M.	D 9h. 0m.; H 9h. 8m.

MAGNETOMETER DISTURBANCES—*continued.*

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
1895.					
21	66	VII.	8	10 43 P.M.	D 10h. 27m. H 10h. 26m.
1896.					
22	69	VI.	15	11 46 A.M.	D 11h. 23m. H 11h. 26m.
23	71	VIII.	26	11 22 P.M.	D 11h. 30m. H 11h. 28m.
24	73	IX.	6	0 2 A.M.	D 12h. 7m. H 12h. 8m.
25	76	XI.	1	5 18	D 5h. 31m. H 5h. 28m.
1897.					
26	78	VI.	12	11 29 A.M.	D 11h. 18m.; 11h. 58m. H 11h. 56m. (See records from Bombay.)
27	79	VIII.	5	0 22 A.M.	D 1h. 4m. H 0h. 59m.
28	81	IX.	21	5 28 A.M.	D 6h. 24m. H 6h. 20m.

To the above is added 1896, August 27, D, 10h. 54m., H, 10h. 55m., which agrees with an earthquake recorded in Europe, as, for example, at Catania at 10.52.

Out of the Utrecht records there are apparently thirteen instances, viz., Nos. 2, 5, 9, 11, 13, 14, 15, 18, 19, 20, 21, 22, and 26, in which the magnetometer perturbations have preceded the records of the seismographs by intervals varying between a few minutes and two hours.

The disturbances due to earthquakes are usually easily distinguished from ordinary magnetic disturbances and from those produced artificially, as for example by the approach and removal of masses of iron.

A copy of these disturbances was forwarded to Dr. Charles Chree, who very kindly compared the same with his own records obtained at Kew. The results were as follows :—

No. 2. Nothing special at the times specified. For several days about this date innumerable small movements occurred from time to time.
,, 5. D, a little movement about 11.25, but not at times stated. H, small movement at 10, but various similar movements both before and after.
,, 9. D, no movement at 1.42, 1.51, or 1.56. H, a small movement at 1.57.
,, 11. D, nothing at the time stated. H, nothing at 9.51 or 9.58.
,, 13. D, numerous very small tremors for some hours before and after time stated. H, nothing at 8.20.
,, 14. D, nothing at 11.20 or 11.34, or 1.34 A.M. on the 2nd. H, nothing at 11.36 P.M. on the 1st.
,, 15. D, curve disturbed this and previous day. Hundreds of movements.
H ,, ,, ,, ,, ,, ,, ,,
,, 18. D, nothing at 10.28 specially. Very small tremors 10.25 to 11.30. H, nothing at 10.1; burr on curve at 10.35.
,, 19. D, microscopic tremors about 7.48 and later. H, nothing at 9.0.
,, 20. D, considerable magnetic movement 6 to 10 P.M. Nothing special at 9 P.M. H, ditto.
,, 21. D, nothing at 10.27 or 10.43. H, nothing at 10.36 or 10.43.
,, 22. D, nothing at 11.23 or 11.46 A.M. H, lot of tiny tremors 10 A.M. to 1 P.M.; nothing special at 11.26.
,, 26. D, nothing at 11.18, 11.29, or 58 ; but at 11.38 somewhat abnormal jerk, and small movement at 11.50. H, nothing at 11.29. Movement that might well be an earthquake from 11.47 to 12.10. This is certainly not a normal magnetic movement.

Referring to the Utrecht times given for the above thirteen cases, Dr. Chree says that in some cases there was in progress either a moderately developed magnetic storm, or a series of vibrations such as are every now and then conspicuous for some time—hours or days. At such times fifty or a hundred tiny wobbles may be observed within a comparatively small time, and it would be almost impossible, in fact, not to have one within a minute or so of any specified time.

Magnetic Disturbances recorded at Det Danske Meteorologiske Institut, Copenhagen. Director, Dr. ADAM PAULSEN.

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetic Disturbances
				1893.	
				H. M.	
1	30	III.	2	11 0 P.M.	Very weak traces in H F at 11h. 3m. P.M.
2	34	IV.	8	1 51 P.M.	Shocks in D and H at 2h. 3m. to 2h. 13m. P.M.
				1894.	
3	57	IV.	27	7 55 P.M.	Disturbances by details not received (J. M.)
4	60	VII.	10	10 30 A.M.	Commenced 10h. 36m. A.M. At 10h. 39m. severe shock, succeeded by several shocks until 10h. 52m. A.M.
5	61	VII.	12	2 17 P.M.	Between 2h. 15m. and 2h. 21m. P.M.
				1895.	
6	66	VII.	8	10 43 P.M.	Between 10h. 47m. P.M. and 11h. 12m P.M. Severe shocks particularly in H F.
				1896.	
7	76	XI.	1	5 18 A.M.	Traces of earthquakes between 5h. 22m. and 5h. 28m.
				1897.	
8	78	VI.	12	11 29 A.M.	Severe shocks between 11h. 18m. and 11h. 57m. A.M.

Magnetometer Disturbances recorded at the K. K. Anstalt für Meteorologie und Erdmagnetismus, Wien, Oesterreich. Director, Dr. J. M. PERNTER.

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
				1893.	
				H. M.	
1	34	IV.	8	1 51 P.M.	Apparently strong movement
2	42	VI.	3	4 25 P.M.	Strong swinging
3	52	VIII.	6	7 42 P.M.	Much disturbed
				1896.	
4	69	VI.	?	11 46 A.M.	On the 16th much disturbed

To the above is added the disturbance caused by the Laibach earthquake, April 14, 1895, at 10.18 A.M.

The origin of No. 1 was South-west Germany; that of No. 2, which is one of the largest and longest earthquakes yet recorded, is unknown; No. 52 was in Italy; while 69 was in Japan.

The magnetographs are but rarely disturbed, and then, with one exception, only by local shocks.

Magnetometer Disturbances recorded at the K. und K. Hydrographisches Amt. Pola.
THE DIRECTOR.

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetometer Disturbances
				1893.	
				H. M.	
1	10	II.	1	0 39 A.M.	10h. 45m. P.M. (?)
2	21	—	9	6 13 P.M.	3h. 35m. P.M. and 5h. 5m. P.M.
3	54	VIII.	14	7 48 P.M.	4h. 37m. P.M.
				1894.	
4	55	III.	22	10 37 A.M.	10h. A.M.
5	61	VII.	12	2 17 P.M.	1h. 10m. P.M.
				1895.	
6	65	I.	18	2 37 P.M.	55m. P.M.
7	67	VIII.	9	5 38 P.M.	1h. 5m. P.M.
				1897.	
8	77	I.	10	9 18 P.M.	8h. 35m. P.M.
9	18	IX.	21	5 28 A.M.	1h. 10m. P.M.

To the above is added a magnetometer disturbance, April 14, 1895, 10 hrs. 22 mins. P.M., which probably corresponds to an earthquake *felt* and recorded throughout many parts of Italy, April 14, at 10 hrs. 18 mins. (in Rome). The origin of this was near Laibach, in Austria.

For the earthquakes recorded but not felt in Europe, the Pola disturbances, with one exception, are from one to four hours in advance of the seismograph records.

Meteorological Office, Toronto, Canada. Director, Professor R. F. STUPART.

Professor Stupart writes me that he has compared the list of earthquakes with the magnetometer traces prior to their disturbance by the electric trams, and does not find upon them any irregularities at the specified times.

Magnetometer Disturbances recorded at Bombay Government Observatory.
N. A. F. MOOS, *Director.*

In the list on p. 238 the earthquakes referred to are those which were recorded in Europe. Several of these had submarine origins the positions of which are unknown (see List, p. 227).

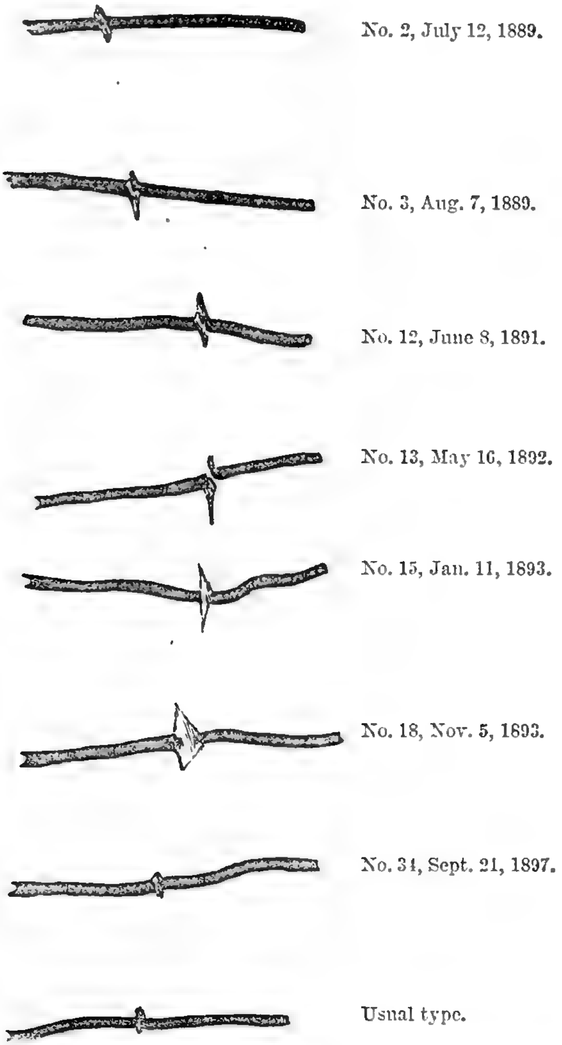
The peculiarity of the movements of the magnets, the fact that they are disturbed by movements which are not perceptible, that the same movements originated at great distances, and that in some instances they

Government Observatory, Bombay. Magnetograph Disturbance, presumably due to Seismological Disturbance. N. A. F. Moos, *Director.*

No. at Government Observatory, Colaba	Corresponding Slide No.	Date on which there was vibration	Time G.M.T. Civil 0 or 24 hour equal to midnight	Instruments Affected. H=Horizontal Force D=Declination V=Vertical Force	Approximate amplitudes of vibration of H in C.G.S. units		Remarks
					Increasing	Decreasing	
			H. M.				
1		1889, February 16	8 52 A.M. to 10 29 ,,	H	·00005	·00005	5 very small shocks at intervals. Earthquake records not commenced.
2	2	,, July 12	7 46 A.M.	H+D	·00007	·00007	Small. Vibration trace slant-wise, presumably due to vibration, first performed round a raised zero (increasing H F) and latterly round lowered zero. Quetta earthquake, July 11, 10h. 22m. P.M., to July 12, 5h. 22m. A.M.
3		,, August 7	7 49 ,,	H+D	·00007	·00012	Lower amplitude good deal larger.
4		,, ,, 8	1 19 P.M.	H+D	·00007	·00009	Small.
5		,, ,, 21	0 25 ,,	H+D	·00005	·00007	Very small.
6		,, ,, 22	0 17 ,,	H+D	·00005	·00006	,, ,,
7		,, ,, 23	1 29 ,,	H	·00005	·00006	,, ,,
8		1890 ,, 2	6 11 ,, to 6 15 ,,	H+D+V	·00012	·00010	All instruments affected. Strongly marked. No earthquake observations during this period.
9		1891, March 7	6 17 A.M.	H	·00007	·00007	Feeble, but well marked.
10		,, April 11	4 49 ,,	H	·00009	·00010	Small and well marked.
11		,, May 6	5 44 P.M.	H	·00007	·00005	Very small, not well marked.
12		,, June 8	7 57 A.M.	H+D	·00011	·00010	Strong, very well marked.
13		1892, May 16	2 16 ,,	H	·00011	·00020	Feeble, but very well marked. Large eqke., May 17, 1h. 41m. to 4h. 13m. P.M.
14		,, October 16	6 19 ,, to 6 57 ,,	H	·00006	·00009	4 separate and distinct shocks. Earthquake, 11h. 52m. to 13h. 40m. P.M., on October 17.
15		1893, January 11	8 30 P.M.	H	·00021	·00025	Strong and very well marked. Beginning abrupt and sudden. Earthquake, January 11, 1h. 18m. P.M.
16	21, 22	,, February 9	8 10 A.M.	H+D	·00008	·00008	Very feeble and faintly marked. Large earthquake, February 9, 6h. 13m. to 8h. 28m. P.M. Origin, Turkey or Japan.
17		,, October 8	11 26 ,,	H	·00004	·00005	Very faint and feebly marked.
18		,, November 5	4 2 ,, to 4 9 ,,	H	·00014	·00012	Heavy and well marked. Beginning gradually and coming to a maximum within 2 minutes after commencement, and then gradually subsiding. Large earthquake, 3h. 56m. to 6h. 0m. A.M. Origin, Tashkent.
19		1895, February 7	2 14 P.M.	H+D	·00005	·00004	Feeble.
20		,, ,, ,,	3 14 ,, to 3 19 ,,	H	·00005	·00005	
21		,, ,, ,,	3 29 ,,	H	·00006	·00006	
22		,, ,, 20	9 41 ,,	H+D+V	·00010	·00021	All instruments affected. Well marked.
23		,, ,, 26	7 58 A.M.	H	·00006	·00005	Small.
24		1896, February 13	8 21 ,,	H+D	·00005	·00009	Well marked.
25		,, March 16	5 29 P.M. to 5 33 ,,	H	·00011	·00013	Well marked and heavy.
26	72	,, May 28	0 24 ,,	H	·00006	·00006	Small.
27		,, ,, ,,	4 23 ,,	H	·00005	·00005	,,
28		,, ,, ,,	4 31 ,,	H	·00005	·00006	,,
29		,, ,, 31	0 30 ,,	H	·00007	·00007	Small and feeble.
30	72	,, August 31	11 29 A.M. to 11 31 ,,	H+D	·00005	·00006	Small. August 31, earthquake, 8h. 23m. A.M.; duration, 2 hours.
31		,, October 31	11 17 ,,	H	·00005	·00005	Small. October 30, 11h. 50 m. P.M. to 0h. 20m. A.M. on the 31st. Also November 1, 5h. 5m. A.M.; duration, 2 hours.
32		,, ,, ,,	0 46 P.M.	H	·00005	·00005	Small.
33		,, ,, ,,	1 39 ,,	H	·00004	·00004	,,
34	81	1897, September 21	5 49 A.M.	H	·00007	·00007	,, well marked. Sept. 21, earthquake, 5h. 28m. A.M. Origin, Borneo.
35		,, ,, 29	0 16 P.M.	H	·00005	·00004	,, ,, ,,
36		,, December 4	3 54 ,,	H	·00005	·00004	

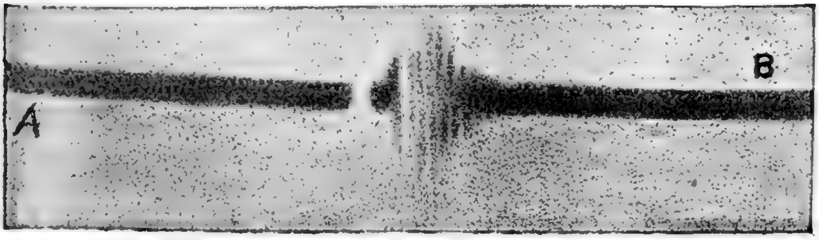
were but feebly pronounced near to their origins, inclines Mr. Moos to the opinion that the disturbances are at least partly magnetic.

FIG. 6.



Sketches of Magnetometer Disturbances recorded at Bombay. N. A. F. Moos.

FIG. 7.



Bombay, June 12, 1897. Disturbance of Declination Needle. Multiplication, $2\frac{1}{2}$ times. N. A. F. Moos.

In the Bombay Magnetic and Meteorological Observations Mr. Moos describes in some detail the disturbances he noted in connection with the Assam earthquake of June 12, 1897.

Dines' Pressure Tube Anemometer Chart did not show any trace of atmospheric disturbance. The barograph trace was, however, disturbed, the maximum effect being about 1 min. later than the maximum disturbances in the declination and vertical force magnetograms. These instruments are of the Kew pattern. The needle of the declinometer has a period of 5·33 seconds, and the disturbance it suffered is here shown enlarged about 2½ times. The time of vibration of the needle of the horizontal force magnetograph, which shows an equally large disturbance, is 8 seconds. The disturbance in the vertical force magnetograph, which is also pronounced, continued over three minutes. There are fourteen fairly regular waves in 29 mins.; that is, the magnet which, if mechanically disturbed and allowed to return to rest, would do so in double swings of 5·33 secs. came to rest with periodic movements, each of which had a duration of two minutes. In Europe the earth-waves from the earthquake had periods of from 10 to 15 secs., and it is likely that when they passed Bombay their periods would be about five seconds. It is difficult to understand how a movement of this description would result in the displacements recorded; and, as Mr. Moos points out, it is equally difficult to see why earth-waves could mechanically cause a change in the scale reading of this type of instrument. His conclusion is that the seismic convulsion was in some way the cause of a magnetic action, every seismic wave having its companion effect in a magnetic wave.

The following is a summary of disturbances of magnetic needles at various observatories by the shock of June 12, 1897 (see Earthquake No. 105, p. 204) :—Time at origin, about 11 hrs. 4 mins. A.M.; arrival of preliminary tremors in Europe, about 11 hrs. 17 mins.; arrival of large waves in Europe, about 11 hrs. 47 mins.

Place	D	H	V	Remarks
	H. M. H. M.	H. M. H. M.	H. M. H. M.	
Bombay .	11 14–11 16	11 11–11 14	11 14–11 19	1st Shock
	11 17–11 43 max.	11 45 End	11 19–11 23	2nd Shock
Batavia .	11 22	11 23, 11 34, 11 37, 11 54	11 29 max.	4 Shocks for H
Utrecht .	11 17–11 19 max.	11 45–12 20		D has two max. of 10 & 15 mm., which for H are 10 & 7 mm.
	11 45–12 30	12 35– 1 30		
Wilhelmshaven	11 19–11 25	11 18–11 39	11 26–11 59	
	11 44–12 0			
Pawlowsk		11 17–11 25		Max. of H at 11h. 22m.
		11 19–11 42		
Para Saint Maur	11 27	11 27		Small
Kew . .				Small & doubtful
Copenhagen				Disturbed

Magnetographs at Lyons, Perpignan, Pola, Vienna, Uccle, and Lisbon were not disturbed.

The barograph disturbance at Bombay was at 11 hrs. 14 mins. to 11 hrs. 21 mins., with max. at 11 hrs. 13 mins.; the electrometer disturbance at Batavia was at 11 hrs. 16 mins. (exact).

Magnetometer Disturbances recorded at the Royal Alfred Observatory, Mauritius. Disturbances are indicated as: s = small; vs = very small; a = abrupt; va = very abrupt; sa = small abrupt. Director, T. F. CLAXTON, Esq.

No.	No. on list p. 227	Month	Day	Time of Earthquake	Magnetic Disturbances
					1889
1	1	IV.	18	5 21 A.M.	H 7h. 35m. A.M.–8h. 10m. vs, 9h. 45m.–10h. 0m, vs, 11h. 10m.–13h. 10m.
2	2	VII.	11	10 22 P.M.	H 3h. 40m. P.M.–4h. 40m. vs, 5h. 30m.–6h. s, 7m. vs. V 3h. 40m.–6h. 10m. vs
3	3	VII.	28	3 30 P.M. 6 0 P.M.	H 5h. 50m. P.M.–6h. 20m. vs, 7h. 10m.–9h. 10m. vs, 10h. 10m. to 2 A.M. on 29th, vs
4	5	VIII	25	7 37 P.M.	H 3h. 40m. P.M.–5h. 20m. vs, 5h. 50m.–6h. 40m., 7h. 37m.–9h. 10m. vs. V 4h. 10m.–8h. 10m. vs
					1891
5	6	X.	27	9 38 P.M.	H 4h. 40m. P.M.–5h. 40m., 7h. 30m.–8h. 10m. s. D 4h. 46m. vs–7h. 35m. vs
					1892
6	7 & 8	III.	16	1 22 P.M. 5 22 P.M.	H 15d. 8h. 40m. P.M.–9h. 20m. V 9h. 10m.–9h. 20m. a
7	11	X.	19	4 21 A.M.	H 7h. 0m. A.M.–7h. 40m. vs. D 4h. 10m.–5h. 40m. vs. V 4h. 40m.–5h. 10m., 7h. 0m.–7h. 40m. vs
8	12	XI.	4	5 24 P.M.	H 2h. 28m. A.M.–5h. 40m. vs. D, like H, also on the 5th. V, like H, also on the 5th, sa
9	14	XII.	9	1 19 A.M.	H 8d. 8h. 10m. A.M. and 11h. 10m.–5h. 10m. P.M. s. D like H, but vs. V 8h. 10m.–1h. 10m. P.M.
					1893
10	16	I.	28	11 46 P.M.	H 7h. 25m. P.M.–11h. 10m. vs, 29d. 9h. 10m. a. V 7h. 38m. P.M.-7h. 43m., 8h. 10m.–8h. 20m.
11	19	II.	6	5 7 P.M.	H 1h. 10m. P.M.–7d. 9h. 10m. A.M. vs
12	21	—	9	6 13 P.M.	H 6h. 10m. P.M–7h. 10m. vs, a wave
13	22	—	9	9 40 P.M.	H 10h. 10m. P.M. – 10h. 40m. vs, 10d. 0h. 10m. A.M. vs, 1h. 40m. vs. D 10d. 4h. 10m. a–5h. 10m. vs
14	24	—	13	5 0 P.M.	H 4h. 10m. P.M.–5h. 10m. vs. D 11h. 50m. A.M.-12h. 0m. vs
15	25	—	16	5 17 A.M.	D 15d. 4h. 10m. A.M. s–8h. 40m. vs, 9d. 40m. P.M.–11h. 40m. vs, 16d. 1hr. 10m. A.M.–5h. 10m. s. V 15d. 9h. 40m. P.M.–10h. 40. H, a small magnetic disturbance, February 14–18
16	30	III.	2	11 6 A.M.	H 11h. 0m. P.M.–0h. 10m. A.M. shallow wave
17	31	—	14	6 20 A.M.	H 5h. 50m. A.M.–1h. 11m. P.M.
18	33	—	23	8 43 P.M.	H 5h. 40m. P.M. s
19	34	IV.	8	1 51 P.M.	H 5h. 10m. A.M.–11h. 10m. s. D like H but faint
20	35	—	17	5 48 A.M.	D 4h. 40m. A.M. vs

MAGNETOMETER DISTURBANCES RECORDED AT THE ROYAL ALFRED OBSERVATORY, MAURITIUS—*continued.*

No.	No. on list p. 227	Month	Day	Time of Earthquake	Magnetic Disturbances
21	37	—	29	6 2 P.M.	H 6h. 40m. P.M. vs
22	39	V.	18	2 39 P.M.	H 9h. 40m. A.M. s–1h. 10m. P.M. vs, 2h. 40m.–3h. 25m. s. D 1h. 10m. P.M.–4h. 10m. P.M. vs
23	41	—	23	8 38 P.M.	H 10h. 25m. P.M.–11h. 10m. s wave. D same as H, but vs wave
24	42	VI.	3	4 25 P.M.	H 2d. 10h. 10m. p.m.–3d. 0h. 10m. A.M. vs, 0h. 40m. A.M.–2h. 10m. vs
25	44	—	11	9 9 P.M.	H 8h. 10m. P.M.–10h. 10m. s wave. D same as H, but vs wave
26	52	VIII.	6	7 42 P.M.	H 4h. 45m. A.M., 7h. 40m.–8h. 10m. va, and movements until 4h. 11m. P.M. D like H, but not abrupt
					1894
27	55	III.	22	10 37 A.M.	H small movements all day. Active from 8h. 10m. A.M.–9h. 10h., but vs. D same as H
28	58	IV.	29	3 25 A.M.	H 28d. 4h. 10m. P.M.–5h. 10m. P.M. s, 29d. 8h. 10m. A.M–10h. 10m. A.M., 11h. 10m.–0h. 10m. P.M. vs, 0h. 30m. P.M.–2h. 10m. vs, 6h. 50m. 8h. 10m. D 29d. 8h. 10m. A.M.–10h. 10m. vs, 6h. 50m. P.M.–8h. 10m. vs. V occasional small movements, 29d. 8h. 10m. A.M.–3h. 10m. P.M.
29	59	VI.	20	5 45 A.M.	H 19d. 4h. 10m. P.M. sa, 21d. 1h. 0m. A.M. D 20d. 4h. 10m. A.M.–8h. 10m. s. V 20d. 7h. 40m. A.M. vs
30	62	IX.	7	11 40 A.M.	H 11h. 40m. vs
31	64	—	27	9 8 P.M.	H 8h. 15m. P.M.–11h. 40m. s wave. D like H. V like H, but vs
					1895
32	65	I.	18	2 37 P.M.	H 9h. 10m. A.M. – 1h. 25m. P.M. vs tremors, 4h. 10m. P.M.–6h. 10m. P.M. wave, 8h. 10m. P.M.–9h. 10m. P.M. D 2h. 10m. A.M.–4h. 10m. A.M. vs, V 8h. 10m. P.M.–9h. 10m. P.M. s wave
33	66	VII.	8	10 43 P.M.	H 9d. 4h. 10m. A.M.–7h. 40m., 9h. 10m.–4h. 10m. P.M., 5h. 10m. P.M.–7h. 25m., 8h. 25m.–10h. 25m. vs tremors
34	67	VIII.	9	5 38 P M.	H 5h. 10m. P.M.–7h. 10m. vs, 9h. 25m. P.M.–0h. 25m. A.M. vs
35	68	XI.	13	9 31 P.M.	H 7h. 40m. P.M.–8h. 40m. P.M. wave, 10h. 10m. to midnight occasional s tremors. D 7h. 40m. P.M.–8h. 40m. P.M. s wave. V like D
					1896
36	69	VI.	16	11 46 A.M.	H 7h. 40m. A.M.–10h. 10m. P.M., a small disturbance. D and V like H
37	70	VI.	29	9 2 P.M.	H 12h. 10m. P.M.–30d. 1h. 10m. A.M., slight movements
38	72	VIII.	31	8 23 A.M.	V 29d. 11h. 10m. P.M.–30d. 0h. 10m. A.M., 8h. 10m. A.M.–9h. 10m. A.M.
39	75	IX.	22	4 53 A.M.	V 4h. 10m. A.M.–5h. 10m. vs

MAGNETOMETER DISTURBANCES RECORDED AT THE ROYAL ALFRED OBSERVATORY, MAURITIUS—*continued.*

No.	No. on List p. 227	Month	Day	Time of Earthquake	Magnetic Disturbances
			1897		
40	77	I.	10	9 18 P.M.	H 4h. 40m. P.M. va, small distance after until midnight. V like H
41	78	VI.	12	11 29 A.M.	H 2h. 10m. P.M. a
42	80	IX.	20	7 24 P.M.	D 4h. 10m. A.M.–5h. 10m. vs
43	81	IX.	21	5 28 A.M.	H 5h. 40m. A.M.–10h. 10m. vs
44	83	XII.	29	11 40 A.M.	H small disturbance all day, sharp at 4h. 15m. P.M.–4h. 35m V like H, only very small

An examination of the above table, for which I am indebted to Mr. T. F. Claxton, the Director of the Royal Alfred Observatory, shows the following results :—

Cases in which magnetic needles have been disturbed at intervals varying between a few minutes and 30 hours *before* an earthquake, 32.

Cases in which magnetic needles have been disturbed at intervals varying between a few minutes and 6 hours *after* an earthquake, 11.

Case in which the disturbances of magnetic needles have accompanied an earthquake, 1.

Observations at the Magnetic and Meteorological Observatory, Batavia.
By Dr. J. P. VAN DER STOK.

June 12, 1897 (Assam Earthquake) (see Earthquake No. 105).

	G.M.T. H.	M.	S.
Horizontal Force, first shock	11	23	40 A.M.
„ „ second „	11	34	40
„ „ third „	11	37	40
„ „ last „	11	54	40
Declination, mid. of motion	11	22	40
Vertical Force, maximum	11	29	40
Electrometer (Mascart), exact commencement	11	16	40

September 20, 1897 (see Earthquake No. 133).

	H.	M.	S.
Horizontal Force	7	16	20 P.M. very small.
Electrometer	7	14	20 large.

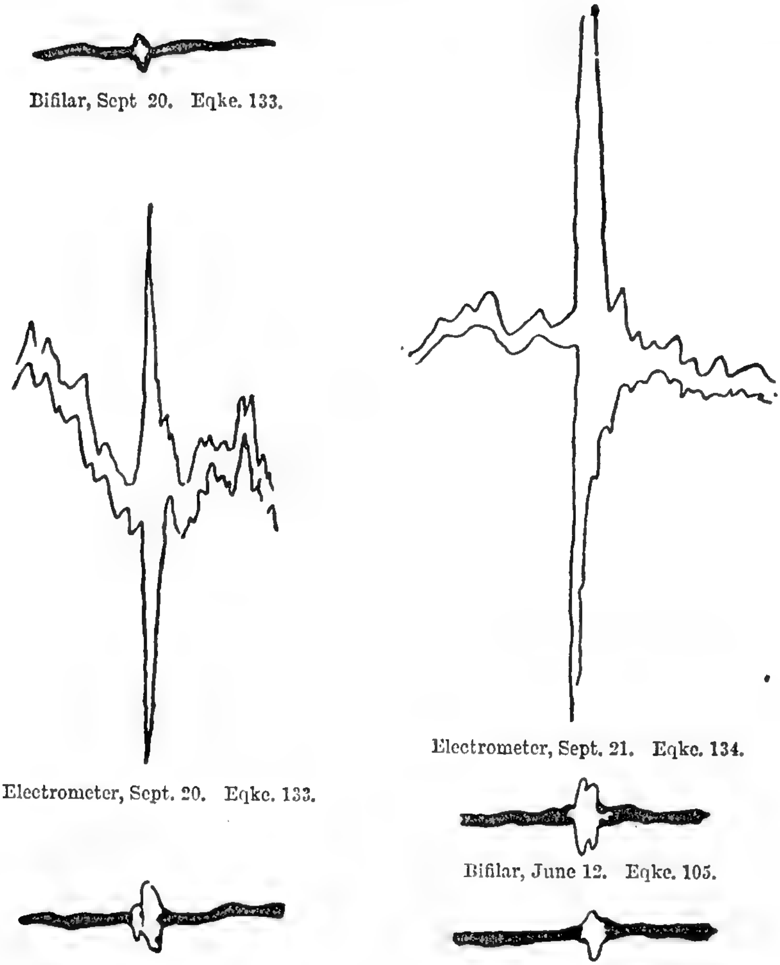
The declinometer and balance were not disturbed.

September 21, 1897 (see Earthquake No. 134).

	H.	M.	S.	H.	M.	S.	H.	M.	S.
Horizontal Force	5	19	20 A.M.	5	24	20			
	5	25	20	5	30	20	5	33	20
	5	39	20 and	5	42	20			
Declination at	5	26	20 A.M. slight.						
Vertical Force	5	23	20 (maximum). Duration 20 mins.						
Electrometer	5	21	20 A.M. (commencement).						

The distance from Batavia to the origin of these last two disturbances is 1,500 kms. The last of them also disturbed magnetometers in the Mauritius, Bombay, Pola, and Utrecht.

FIG. 8.



Bifilar, Sept 20. Eqke. 133.

Electrometer, Sept. 20. Eqke. 133.

Electrometer, Sept. 21. Eqke. 134.

Bifilar, June 12. Eqke. 105.

Bifilar, Sept. 21. Eqke. 134.

Vertical Force, June 12. Eqke. 105.

Magnetometer and Electrometer disturbances. Batavia, 1897.

Magnetometer Disturbances noted at the Magnetisch en Meteorologisch Observatorium, Batavia.

No.	No. on List p. 227	Month	Day	Hour	Magnetometer Disturbances
					1892
				H. M.	
1	15	XII.	20	0 34 A.M.	Dec. 19, 11h. 3m. P.M. Very slight.
					1893
2	21	II.	9	6 13 P.M.	6h. 19m. P.M. Pretty distinct.
					1895
3	65	I.	18	2 37 P.M.	2h. 14m. P.M. Faint (?).
4	66	VII.	8	10 43 P.M.	4h. 5m. P.M. to 4h. 11m. P.M. Clear (?).

MAGNETOMETER DISTURBANCES NOTED AT BATAVIA—*continued.*

No.	No. on List p. 227	Month	Day	Hour	Magnetometer Disturbances
				1896	
5	71	VIII.	26	11 22 P.M.	2h. 45m. P.M. and 2h. 49m. P.M.
6	76	XI.	1	5 18 A.M.	Nov. 2, 11h. 58m. A M. to 0h. 8m. P.M. (?)
				1897	
7	78	VI.	12	11 29 A.M.	11h. 25m. A.M. to 11h. 50m. A.M. Strong.
8	80	IX.	20	7 24 P.M.	7h. 17m. P.M. to 7h. 33m. P.M. Not strong.
9	81	IX.	21	5 28 A.M.	5h. 24m. A.M. to 5h. 45m. A.M. Strong.

Magnetometer Disturbances noted at the Observatory, Zikawei, China.

No.	No. on List p. 227	Month	Day	Hour	Magnetometer Disturbances
				1889	
				H. M.	
1	1	IV.	18	5 21 A.M.	2h. 54m. and 4h. 24m. Small serrations.
2	4	VII.	28	6 0 P.M.	4h. 49m. to 1h. 54m. Small notched movements.
				1891	
3	6	X.	27	9 38 P.M.	9h. 39m. A remarkable mechanical disturbance. See 'La Nature,' 1892, No. 975, p. 149.
				1892	
4	7	III.	16	1 22 P.M.	1h. 54m. to 5h. 54m. Slight agitation.
5	11	X.	19	9 41 A.M.	Perturbations the day before and after. On the 4th, perturbations from 2h. 9m. A.M.
				1893	
6	19	II.	6	5 7 P.M.	3h. 54m., trepidations. Large perturbations at 5h. 27m.
7	24	II.	13	5 0 P.M.	4h. 14m. to 5h. 4m. Slight undulations.
8	25	II.	16	5 17 A.M.	All day on the 16th and 17th a great perturbation, but nothing exceptional at the time of the earthquake.
9	44	VI.	11	9 9 P.M.	3h. 54m. to 9h. 9m. Light undulations.
10	53	VIII.	10	9 9 P.M.	3h. 54m. to 7h. 54m. Small serrations.
				1894	
11	55	III.	22	10 37 A.M.	Great perturbations on the 22nd and 23rd, but nothing special at the time of the earthquake.
12	59	VI.	20	5 45 A.M.	Two days of remarkable perturbations, but nothing remarkable at the time of the earthquake.
13	62	X.	7	11 40 A.M.	9h. 54m. A.M. to 3h. 54m. P.M. Slight serrations.
14	64	X.	27	9 8 P.M.	3h. 54m. to 9h. 54m. Marked oscillations.
				1895	
15	65	I.	18	2 37 P.M.	11h. 54m. to 1h. 54m. Several insignificant movements.
16	67	VIII.	9	5 38 P.M.	At 3h. 54m. a disturbance lasting two days began.

Father Chevalier, who kindly sent me the above notes, remarks that the most striking feature of the comparison appears to be that there is no relation between earthquakes and magnetic disturbances. A slight earthquake which was felt at Zikawei on June 4, 1898, was, however, recorded by a mechanical motion of the magnetic needles. In the sixteen cases where something has been noted at or about the time of large earthquakes, it must be observed that eleven of these refer to disturbances which originated in Japan or Manila, and in nine of these eleven cases perturbations preceded the occurrence of the earthquakes. We have here something analogous to what has been observed in Japan. If we omit the three instances (nine, ten, and sixteen) where there have been slight movements of the magnetic needles at about the time when small shocks were recorded in Italy, it hardly appears to be a mere coincidence that the Zikawei register is practically confined to records of earthquakes which have originated in localities not far removed from that observatory. If it were a coincidence, then we should expect to find similar perturbations preceding at least a few of the remaining sixty-seven earthquakes on our list. Inasmuch as certain of these earthquakes, as, for example, those originating in Borneo and N.E. India, in every probability gave rise to as much mechanical movement at Zikawei as those originating in Japan, it seems that the instruments at that station are but very rarely disturbed by the mere movement of the ground.

Extracts from the 'Bollettino della Società Sismologica Italiana,' 1895, 1896, 1897.

No.	Nos. corresponding to those in List p. 227	Earthquake				Magnetograph Disturbances
		Month	Day	Hour	Place of Observation	
				1895		
				H. M.		Place
1		III.	6	9 28 A.M.	Rome	Potsdam = 0.
2		VI.	15	4 26 P.M.	„	Utrecht. Magnetographs disturbed 4h. 5m. P.M. No disturbances at Pola, Potsdam, Pawlowsk, Wilhelmshaven, Toronto, Stonyhurst, and Vienna.
3	66	VII.	8	10 43 P.M.	Padua	Pawlowsk. D and H disturbed. Potsdam. D, 10h. 44m. H, 10h. 50m. V, 10h. 50m. Wilhelmshaven. D, 10h. 47m. HF, 10h. 49m. V, 10h. 40m. Utrecht. D, 10h. 27m. H, 10h. 26m. Pola. D, 10h. 52m. Toronto, Stonyhurst, and Vienna = 0.
4		XI.	2	0 25 A.M.	Rome	Potsdam. V, 32m. to 35m. Amplitude 1′.

EXTRACTS FROM THE 'BOLLETTINO DELLA SOCIETÀ SISMOLOGICA ITALIANA,' 1895-7—*continued.*

No.	Nos. corresponding to those in List p. 227	Earthquake				Magnetograph Disturbances
		Month	Day	Hour	Place of Observation	
					1896	
5		I.	9	12 14 P.M.	Rome	Potsdam. V, 2h. 8m., 2h. 13m., and 2h. 18m.
6		III.	4	4 33 A.M.	„	Potsdam. D, 2h. 52m. to 5h. 9m. H, 4h. 43m. to 5h. 2m. V, 4h. 50m. to 4h. 56m. Utrecht. D slight. H, 4hr. 55m. to 5h. 23m.
7		IV.	10	9 28 A.M.	„	Potsdam. V, 9h. 38m. to 9h. 42m. Amplitude about 0′·5.
8		V.	2	1 21 P.M.	„	Potsdam and Utrecht = 0.
9			3	2 55 P.M.	„	„ „ „ „
10			5	11 39 P.M.	„	„ „ „ „
11	69	VI.	15	11 19 A.M.	„	Utrecht. D, 11h. 23m. to 11h. 46m. H, 11h. 26m. to 12h. 16m.
12	71	VIII.	26	11 23 P.M.	„	Wilhelmshaven. D, 11h. 28m. to 11h. 31m. H, 11h. 29m. to 11h. 32m. V, 11h. 25m. to 11h. 44m. Utrecht. D, 11h. 29m. to 11h. 49m. H, 11h. 27m. to 11h. 55m. Potsdam. D, 11h. 31m. to 11h. 59m. Amplitude 2′·5. Potsdam. H, 11h. 29m. to 11h. 40m. Amplitude 1′. Potsdam. V, 11h. 35m. to 11h. 37m. the maximum.
13			27	11 0 A.M.	„	Wilhelmshaven. All three instruments disturbed at 10h. 57m., 11h., and 11h. 1m. Utrecht. D, 10h. 53m. to 11h. 6m. H, 10h. 54m. to 11h. 3m. Potsdam. D, 11h. 2m. to 11h. 35m. H, 11h. 7m. V, 11h. 5m.
14	72		31	8 21 A.M.	„	Wilhelmshaven. D, 8h. 54m. to 9h. 2m. H, 8h. 56m. to 9h. 9m. V, 8h. 30m. Potsdam and Utrecht no disturbance.
15	73	IX.	6	0 2 A.M.	„	Wilhelmshaven. D, 29m. to 13m. H, 7m. to 10m. V, 4m. to 29m. Utrecht. D, 6m. to 19m. H, 7m. to 31m. Potsdam. D, 12m. to 24m. H, 11m. to 24m. Amp. 2′. V, 12m. to 20m.
16			12	8 24 A.M.	„	Wilhelmshaven. D, 8h. 51m. to 8h. 54m. H = 0. V, 8h. 30m. to 9h. 1m. Potsdam and Utrecht = 0.

EXTRACT FROM THE 'BOLLETTINO DELLA SOCIETÀ SISMOLOGICA ITALIANA,' 1895-7—*continued.*

No.	Nos. corresponding to those in List p. 227	Earthquake				Magnetograph Disturbances
		Month	Day	Hour	Place of Observation	
17	75		22	4 53 A.M.	,,	Wilhelmshaven. D and H = 0. V, 5h. 3m. to 5h. 12m. Potsdam. D, 5h. 4m. to 5h. 20m. H, 5h. 5m. V, 5h. 7m. (?). Utrecht = 0.
18			23	11 52 P.M.	,,	Wilhelmshaven. D, 3m. to 4m. H = 0. V, 11h. 58m. to 17m. Potsdam. D, 4m. to 14m. H, 9m. to 13m. V (?) Utrecht = 0.
19	76	XI.	1	5 7 A.M.	,,	Wilhelmshaven. D, 5h. 27m. to 5h. 28m. V, 5h. 22m. to 5h. 38m. Potsdam. D, 5h. 21m. to 5h. 41m. H, 5h. 50m. to 5h. 35m. V, 5h. 26m. to, 5h. 35m. Utrecht. D, 5h. 30m. to 5h. 46m. H, 5h. 27m. to 5h. 53m.
20			10	10 43 A.M.	,,	Wilhelmshaven, Potsdam, Utrecht = 0.
				1897		
21		II	7	7 59 A.M.	Shide	Utrecht = 0.
22			15	10 20 P.M.	Potsdam	,, ,,
23			19	8 59 P.M.	Rome	Potsdam. V, 9h. 41m. to 9h. 44m. Amplitude 1′.
24			20	0 18 A.M.	Shide	Utrecht = 0.

Until magnetograph records have been obtained from other observatories, and until special experiments have been made, as, for example, to determine the effect of artificially produced earthquake-like motion upon magnetic needles and the effect of actual earthquakes upon non-magnetic bars so suspended that their periodic movements are identical with those of magnetic needles upon the same supporting pier, we cannot say with certainty whether earthquake waves are or are not accompanied by magnetic waves.

In discussing the records brought together, which refer to the movements of magnetic needles *at the time of* earthquakes, it is important to consider the mechanical movements which occurred at the time of their production.

When a great earthquake has originated, as, for example, in Japan, seismographic records indicate that about 16 mins. later Europe has been swept with a flood of motion, and it might be imagined that one observatory has practically been subjected to as much movement as any other.

The effects on magnetic needles at various observatories have, however, been very different.

At magnetic observatories in England, Pola, Vienna, Copenhagen, Toronto, and other observatories only the slightest perturbations are noted, and these only rarely. On the contrary, at Utrecht, Potsdam, and Wilhelmshaven movements of magnetic needles and the occurrence of seismic waves are comparatively of frequent occurrence.

One explanation for this marked difference in the behaviour of magnetic needles at different stations rests on the fact that these three latter stations stand on the vast plain of alluvial drift which stretches from Holland eastwards across Northern Germany into Russia, and it may be assumed that the seismic waves on this ocean-like expanse of soft materials are slower and larger than those exhibited in the harder materials on or near to which other observatories are situated. Exceptions to such an explanation are, however, found in the records from Copenhagen and Zikawei, and before we can say with certainty that there are great differences in the character of the mechanical movements at different stations, seismometric records must be obtained from the same.

Other reasons which may be adduced to explain why at one set of stations magnetic needles are disturbed, whilst at another set they are practically quiescent may be as follows :—

First, we may assume that at one set of stations the needles have periodic movements which more nearly synchronise with the period of the earth waves than those of needles at stations where magnetometer disturbances are rare.

The only notes hitherto collected which bear on this point are contained in the following table, in which the times given are the intervals in seconds taken to complete a double or back-and-forth circular vibration of declination (unifilar) and horizontal force (bifilar) magnetometers :—

	Unifilar.	Bifilar.
	s.	s.
Stonyhurst	14·30	13·20
Bombay	5·33	8·00
Greenwich	50·00	42·00
There is also an upper declination magnet (for eye observations), with a period for double swing of 61^s approximately.		
Vienna	5·35	15·36
Pola	7·98	
Potsdam	10·00	8·00
Wilhelmshaven	15·9	16·7
Kew	10·5	13·6
Falmouth	17·0	18·8
Antwerp	14·4	18·6
Copenhagen	7·1	4·9

The magnet for horizontal force at Antwerp is kept at right angles to the meridian by deflection magnets.

From the table it will be noted that the periods given for Kew, where disturbances at the time of earthquakes are rare, are not very different for those given for Potsdam, where disturbances are frequent.

A very much more important point, however, is that all large earthquakes commence with a series of short-period waves. Five-second periods are marked. These are followed with others having periods of 10 secs., whilst later there may be waves with periods of 20 and even

60 secs. From this it may be assumed that at all observatories, whatever be the period of the magnets, each of them for a considerable interval of time is subjected to identical or nearly identical periodic movements of their supports.

From this we should expect to find that large earthquakes would disturb magnetometers at all stations.

Sometimes the magnetic needles appear to be disturbed by the short-period preliminary vibrations, and at other times by the succeeding long-period earth waves; and the question arises, whether the mechanical movement these represent is likely to establish a rotational movement in a suspended magnet.

If we regard a magnet and its suspension as an ordinary pendulum, then at all stations we should expect to find that the preliminary tremors of an earthquake would establish a swing accompanied by more or less rotation. When, however, we have rotational movements of magnetic needles accompanying the larger earth waves the explanation of this is not so clear. The tilting which such waves represent may, as an illustration, be taken at 10 secs. of arc. For such a tilt a magnet with a suspension of 12 ins. would be displaced through a distance of about one hundredth of a millimetre, and because the movement would be extremely slow, taking from 5 to 10 secs. of time in one direction, it is likely that the magnet would closely follow its point of support.

When movements of this character take place the resultant movement recorded in the photographic film is a displacement having a range of from 2 to 15 mm., indicating that the magnetic needle has rotated through an arc of from 1 to 7 minutes.

To determine whether tilting so slight and so slow results in so much rotation is obviously a matter which without great difficulty may be solved by experiment.

The second assumption to account for the disturbance of magnetographs at certain stations only, is the hypothesis that with regard to the surface of the earth there is an unequal distribution of a subjacent magnetic material the movements of which influence magnets in its vicinity.

On the surface these movements are apparently represented by waves 20 to 50 km. in length and 20 to 50 cm. in height.

To explain the fact that magnetic storms and perturbations so often precede large earthquakes and but seldom appear to precede small ones (see Registers for Greenwich, Utrecht, Mauritius, Zikawei, &c.), we may assume that the earthquake is preceded by chemical, physical, or mechanical changes in the constitution of the materials where it originates. All that we are certain about is that with many earthquakes there have been enormous mechanical displacements of material sufficiently large to disturb the Pacific Ocean for a period of twenty-four hours.

Other earthquakes from submarine centres which have not disturbed oceans, but have created equally large earth waves, indicate equally large subterranean reliefs in strain and material readjustments.

These large earthquakes, originating beneath the bottom of the steeper slopes of the earth's surface, suggest that at such places a secular flow in subterranean material may be in progress, accelerations in which result in violent shaking, which as it radiates is transformed into slow earth waves.

Near to the scene of such subterranean changes, prior to and at the time of the same, magnetic perturbations should be observable. In Japan such appears to have been the case.

The large sudden subterranean adjustments may not occur on the average more than twenty times per year; but if we attribute the smaller earthquakes to similar activities, one of these may, on the average, take place every half-hour; and although none of these latter is likely to produce an appreciable magnetic effect on the surface of our earth, their cumulative effect after a sufficient interval of time, as representing a rearrangement and new condition of magnetic materials, might possibly result in measurable changes in magnetic elements.

VII. *Sub-oceanic Changes.*

In Section 9 of the Report for 1897 (p. 181) it was stated that off coast lines there was a tendency for sediments and detritus derived from the land accumulating under the influence of gravity to assume unstable contours. That such contours had an existence was shown by reference to soundings. By excessive deposition of sediments, the sub-oceanic escape of waters from subterranean sources, the sudden release of waters backed up in bays by gales, changes in the magnitude and direction of ocean currents, and by sub-oceanic seismic and volcanic action, sudden and extensive yieldings might take place along the faces of slopes in a critical condition. That such sub-oceanic landslides had often taken place was proved by an appeal to the experience of cable engineers, who often found that cable interruptions were the result of their burial along lengths of several miles, the materials covering the lost sections having fallen from the faces of slopes along the base of which the cables had been laid. In a few instances it was noted that there had been a considerable increase in the depth of the ocean along a line of slip. Many examples were given where cable interruption accompanied an earthquake which had a submarine origin, and therefore it may be presumed that it was the earthquake which caused the landslide beneath the ocean, in the same manner that severe earthquakes result in similar displacements of what are probably much more stable surfaces on the land.

It is believed that most of the deep-water cable interruptions on the west side of South America are attributable to sub-oceanic activities of this description, and it was shown that in the Mediterranean, off the coast of Java, and in other parts of the globe, we had from time to time evidences of a very close relationship between seismic activity and the failure of cables.

The fact that earthquakes originating in deep water, as, for example, at a depth of 4,000 fathoms off the N.E. coast of Japan, have been accompanied by a series of sea waves which may agitate an ocean for 24 hours tells us that there must have been a sudden sub-oceanic displacement of a very large body of material, accompanying some form of bradyseismical adjustment.

Although the earthquakes which result from these sudden movements may not be felt or be recordable on a coast at a distance of 200 or 300 miles from their origin, they may often be noted in the records obtained from instruments which are capable of registering the slower movements of the earth's surface at distances of many thousands of miles from their origin. The object of the following table, the materials for which were almost entirely gathered together by my friend Mr. M. H. Gray, of Silvertown, is to indicate the frequency of sub-oceanic disturbance, but by no means to attribute more than a fractional portion of the same to seismic action. The *hours* at which unfelt earthquakes the origins of which have been at great distances from the stations where they were recorded are given with some accuracy, but the times at which cable interruptions have been notified are some time after the interruptions actually occurred. Only those who are in a position to correct these latter dates, and know the circumstances attending the various failures, can determine which of them are likely to have originated from seismic disturbances.

In order to extend our knowledge of sub-oceanic changes, and throwing more certain light upon operations leading to cable interruption, I shall regard it as a great favour if officers of cable companies who may read this report will send me an exact statement of the times at which failures took place, which we know to have happened at *about* the same time as unfelt earthquakes have been recorded, addressing the same to me at the British Association Rooms, Burlington House, London, W., England.

Approximate Time of Cable Failures, and exact Greenwich Time of Unfelt Earthquakes.

No.	Approximate			Name of Cable	Exact time of Earthquakes	
	Month	Day	Time		Day	Hour, G.M.T., & Remarks
				1897.		
			H. M.			
1	I.	5	4 20 P.M.	Hong Kong-Macao .	4	11b. 22m. A.M., & 10h. 52m. P.M.
2	II.	4	9 15 A.M.	Grenada-Trinidad . .	5	7h. 52m. A.M.
3				Maranham-Ceara . .	”	”
4				Ceara-Pernambuco .	”	”
5		6	9 5 A.M.	Jamaica-Colon . . .	”	”
6		10	2 55 P.M.	Emden-Vigo	7	7h. 59m. 3s. A.M.
7		23		Tenedos-Dardanelles .	20 21	0h. 17m. 47s. A.M. 3h. 22m. 0s. A.M.
8		20	3 20 P.M.	Assab-Massowah . .	”	”
9	III.	23		Tenedos-Dardanelles .		Due to ship's anchor.
10				Malta-Alexandria . .		—
11		24		Emden-Vigo . . . . (see 'Electrician,' April 2, 1897)	23	4h. 19m. 12s. P.M.
12	IV.	14		Benguela-Mossamedes		—
13		19	6 30 P.M.	Chio-Syra	17	10h. 43m. P.M. ?
14		20	3 0 P.M.	Hong Kong-Macao .	19	12h. 45m. P.M. ?
15		25	10 20 A.M.	Assab-Massowah . .		—
16		28		Konekry-Sierra Leone.		—
	V.	3	2 55 P.M.	Hong Kong-Macao . .	1	7h. 15m. A.M.
		5	3 20 P.M.	Para-Maranham . .		—
		8	8 40 A.M.	Perim-Assab	8	1h. 52m. 30s. P.M. ?
		21	8 20 A.M.	Assab-Massowah . .		—
		29	8 30 A.M.	Lourenço Marques-Durban	23 24	1h. 15m. 20s. P.M. 0h. 18m. 59s. A.M., 1h. 48m. 19s. A.M., & 4h. 30m. 59s. A.M.
	VI.	2	9 25 A.M.	Grenada-Trinidad . .	3	9h. 57m. 18s. A.M. ?
				Puerto Plata-Martinique	”	”
		24		Shanghai-Foochow .	20	8h. 58m. 40s. P.M.
				Shanghai-Hong Kong .	21	8h. 14m. 43s. P.M.
		25	5 45 A.M.	Bonny-Cameroon . .	22	2h. 11m. 40s. P.M.
					24	7h. 34m. 53s. P.M.

APPROXIMATE TIME OF CABLE FAILURES—*continued.*

No.	Approximate			Name of Cable	Exact Time of Earthquake	
	Month	Day	Time		Day	Hour, G.M.T. & Remarks
	VII.	4	8 20 A.M.	Emden-Vigo		
		13		Zanzibar-Mombassa		—
		15	5 50 P.M.	Accra-Kotonou * (or Porto Novo)		Shock at Laibach. Not recorded at Shide.
		19	2 35 P.M.	Cape Town - Mossamedes	17	7h. 57m. 9s. A.M.
		21		Cayenne-Para	21 22	1h.33m.32s. P.M. Large. 11h. 20m. A.M. Moderate.
		23	8 20 A.M.	Chypre-Lattique.	,,	,,
		28	8 10 A.M.	Aden-Zanzibar		—
	VIII.	7	2 30 P.M.	Cape Town - Mossamedes	5	0h. 22m. 35s. A.M.
				Syra-Chio	,,	,,
	IX.	1or2		St. Vincent-St. Jago	1	6h.29m.41s.P.M. Small.
		4	4 10 P.M.	Mozambique-Lourenço Marques	5	1h. 21m. 59s. P.M. ? Small, but long.
		13	3 30 P.M.	Boulama-Bissao	12	10h. 54m. 18s. P.M. Small.
		28	2 30	Hong Kong-Macao	25	6h. 3m. 39s. P.M. Small.
		29		Cayenne-Pinheiro		
	X.	5	3 10 P.M.	Zanzibar-Seychelles	2 3	1h. 36m. 39s. P.M. 3h. 7m. 9s. P.M.
		11	2 35 P.M.	Otranto-Vallona		—
		18	2 20 P.M.	Mozambique-Lourenço Marques	19	0h. 6m. 52s. A.M. Large.
		23	3 20 P.M.	Amazon beyond Santa Vem	20	2h.43m.59s.P.M. Large.
		25	5 30 P.M.	Paramaribo-Cayenne	23	3h. 19m. 0s. A.M. & 5h. 49m. 56s. P.M.
		26	3 20 P.M.	Cadiz-Teneriffe	23	3h. 19m. 0s. A M. & 5h. 49m. 56s. P.M.
		29	8 45 A.M.	Santiago de Cuba-Guantanamo		—
		7		St. Vincent - Pernambuco	2 3	1h. 36m. 39s. 3h. 7m. 9s.
				No. 1 Cable ('Electrician,' 29.10.97)		
	XI.	4	11 50 A.M.	Bundaberg-New Caledonia		
		8	2 30 P.M.	St. Thomé-Loanda		
				Cayenne-Para		
				Amazon-Manaos		
		22	9 0 A.M.	Ceara-Pernambuco	20 22	5h. 33m. 21s. P.M. 9h. 48m. 45s. A.M.
		27	9 15 A.M.	Vigo-Borkum	25	10h. 1m. 48s A.M.
	XII.	3	8 25 A.M.	San Thomé-Loanda		
		6	3 40 P.M.	Sitia-Rhodes		
		13	2 25 P.M.	San Thomé-Loanda		
		20	4 10	Saigon, Thunau† Cable	17	6h. 30m. P.M.
		23	5 40 P.M.	Ceara-Maranham		
		29	9 40 A.M.	Grenada-Trinidad	28	8h. 54m. 21s. P.M.
		31	4 20 P.M.	CapeHaytien,Puerto Plata, and Puerto Plata-Martinique.	29	11h. 40m. 48s. A.M. This earthquake known cause of failure.

APPROXIMATE TIME OF CABLE FAILURES—*continued.*

No.	Approximate Month	Approximate Day	Approximate Time	Name of Cable	Exact Time of Earthquake Day	Exact Time of Earthquake Hour, G.M.T. & Remarks
				1898.		
	I.	3	8 50 A.M.	Para-Maranham . .	3	2h. 41m. 2s. P.M. & 3h. 7m. 15s. P.M.
		5	6 5 P.M.	Curaçao-La Guayra. .		
		6	9 15 A.M.	Saigon-Hong Kong .		
		13	6 0 P.M.	Para Camela Cable .		—
		23	10 0 A.M.	Para-Maranham . .		
		26		Puerto Plata-C. Haiti..	24	11h. 45m. 49s. P.M.
		27	3 30 P.M.	Paramaribo-Cayenne .		—
		28	2 45 P.M.	Bolama-Bissao		—
	II.	7	8 35 A.M.	Emden-Vigo	5 7	8h. 36m. 13s. A.M. 11h. 35m. 20s. P.M.
		10	5 55 P.M.	Lattique-Chypre . .	8	11h. 5m. 47s. P.M.
					9	10h. 57m. 36s. P.M.
		14	4 0 P.M.	Bolama-Bissao	16	5h. 9m. 8s. P.M.
					18	5h.0m.0s. P.M. Toronto record.
		19	3 45 P.M.	Bolama-Bissao . . .	19	
		28	2 0 P.M.	Aden-Zanzibar . . .		Owing to repairs.
	III.	6	2 5 P.M.	Amazon cable beyond Obidos . .		
		17	8 45 A.M.	San Thomé-Loanda .		To effect repairs.
		19	8 25 A.M.	Gibraltar-Tangier . .		
		19		Lourenço Marques-Durban		
		24	8 20 A.M.	Cayenne-Pinheiro . .		
		28	8 45 A.M.	Havre-Waterville . .		
		28	2 40 P.M.	Odessa-Constantinople		
	IV.	4	5 0 P.M.	Amazon Cable beyond Gurupa		
		9	3 40 P.M.	Sierra Leone-Accra .		
		14	8 0 P.M.	Cape Town - Mossamedes		
		17	10 15 A.M.	Maranham-Para . .		
		20	2 30 P.M.	Benguela-Mossamedes		

* Kotanu; is also called Porto Novo sometimes. (Kotanu is on the *coast*, Porto Novo, a few miles *inland.*)

† Thunau, also called Hué.

The earthquake records are not continued beyond February 19, 1898.

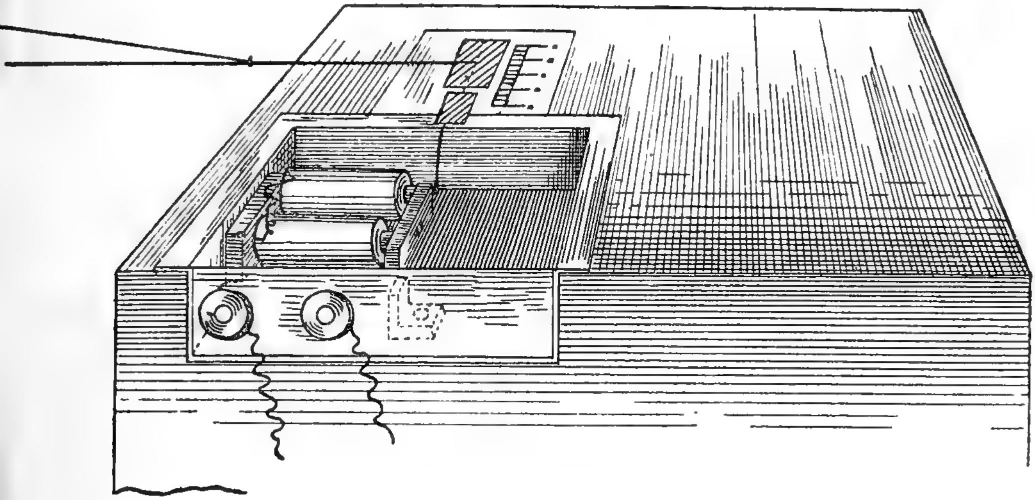
The three breaks which took place in November and December, 1897, on the San Thomé-Loanda line did so at the same place about 150 miles off the north of the Congo, where there is a depth of some 1,300 fathoms.

Mr. R. Kaye Gray points out that here we have a river bed extending seawards as a deep gulley the walls of which are 2,000 feet in height. In 1,550 fathoms a strong under-current renders it difficult to obtain soundings. In the mouth of the Congo there is a depth of only ten fathoms, and it does not seem likely that the rivers flowing over this shallow would dive down to produce the under-tow observed at a distance of 150 miles off the coast. Mr. Gray's idea is that we have here a case of subterranean water bursting out in the bed of the ocean, moving heavy detritus across the cable to cause interruption, whilst lighter particles rise to the surface to discolour the ocean. There is no evidence suggesting that these failures were any way connected with seismic phenomena.

VIII. *A Time Indicator.*

A slight modification in the method of obtaining time marks on the photographic film connected with the Milne Horizontal Pendulum is shown in the accompanying sketch :—

FIG. 9.



The watch, with its eclipse hand (see Report, 1897, p. 138), is replaced by a small electromagnet which every hour, by a current lasting about 20 seconds, holds an eclipse plate over one end of the slit in the lid of the box containing the clock driving the bromide film. The two wires connect with two brass studs in the lower edge of the upper part of the film-box, which fit into brass sockets in the upper edge of the lower half of the same box. From these sockets wires connect with the wheels on the two sides of the box, the rails on which these run leading to a clock giving the required length of contact.

To get this length of contact the Shide arrangement is to prolong the minute hand of a regulator with about $\frac{1}{4}$ inch of platinum wire, which every hour passes through a globule of mercury about the size of a pea, standing *up* in a small insulated iron cup fitted in the brass frame which carries the glass covering the clock face. The only advantage of this arrangement is that it saves a little time in winding and comparing the watch. Two platinum contacts rather than a platinum mercury contact would be preferable.

IX. *On the Civil Time employed throughout the World.*

With the kind assistance of the Foreign Office, the Colonial Office, and the India Office, copies of the following letter have been circulated throughout the world. The text of the circular explains the object in view. Numerous replies have been received from our Colonies, India and its dependencies, but until these have been supplemented by replies from many foreign countries the general report which it is desired to draw up cannot be made. It is hoped that the necessary tabulation may be undertaken for the Report for 1899.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:
Burlington House,
London, W.

SIR,—It is, I think, remarkable that there appears to be no publication which shows the corresponding value in Greenwich mean time of the local time employed throughout the world.

Such a table is indispensable in order to determine accurately the instant of occurrence of earthquakes, sea waves, magnetic phenomena, the despatch of telegrams, and many other events, the sequence of which in absolute time has to be determined.

Although application has been made to the Royal Observatory at Greenwich, to the Royal Geographical Society, to the Central Telegraph Office in London, to the offices of cable companies, and to other possible sources of information, very little has been obtained.

As a Secretary of the British Association Committee whose names are appended, I desire to publish in their forthcoming Report a table showing the differences between Greenwich mean time as used in England and Scotland and that of the civil times used in various parts of the world.

By civil time I mean the time used by railways, telegraphs, and for ordinary public affairs.

If different times are used in various parts of your country, I trust that you will be able to give information relating to the same.

Feeling assured of the value of the table it is intended to compile, I sincerely trust that you will favour me with a full and explicit statement of the time generally employed in your country. If it is mean time, state the meridian; the observatory, or the place to which this refers; and also, as a check against any misunderstanding, please state distinctly the equivalent of December 1, 9 A.M. G.M.T. in the local time, or times adopted in your own country.

I have the honour to remain, Sir,
Your obedient servant,
JOHN MILNE.

X. *Great Circle Distances and Chords of the Earth.*[1]

The highest velocity which can be calculated for the transmission of an earthquake wave is that which is determined when we assume that its path from its origin to an observing station has followed a great circle over the surface of the earth, whilst a lower velocity is obtained on the hypothesis that the movement has passed along a chord through the earth.

Inasmuch as an earthquake origin, especially if submarine, cannot be determined with any degree of accuracy, whilst the origin itself may have dimensions measured by several tens of miles, a simple and sufficiently accurate method of determining great circle distances is to measure the same with a flat steel tape or a piece of thread upon the surface of a globe.

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[1] A table giving the lengths in kilomètres of arcs and chords of the earth has been drawn up by Mr. James Arnott, and the same may be had on application to Mr. J. Milne, a secretary of this committee.

XI. *Tables of Certain Small Fractions of an Hour.*

The film used with the Milne Horizontal Pendulum is supposed to be driven at the rate of 60 mm. per hour. In consequence of changes in temperature, varying resistances in the unrolling of the film, and for other reasons, measurement between the time marks will sometimes slightly vary. The result of this is that the observer when determining the exact commencement of a disturbance finds he has to work out certain fractions of an hour. For example, he may require to know the value of $\frac{31}{59}$ of an hour, or $\frac{31}{59\cdot75}$ of an hour, which are respectively 31 mins. 31·5 secs., and 31 mins. 07·7 sec.

Such results are shown in the following table drawn up by my assistant, Shinobu Hirota.

Inasmuch as measurements less than 0·1 mm. cannot be made on the time scale, it is evident that for all ordinary computations the decimals in the following table are not required (see British Association Report, 1896, p. 183).

Distance from Time Mark to some Phase of a Disturbance	INTERVALS BETWEEN TIME MARKS ON A FILM								
	MM. 58·0 per 1 hour	MM. 58·25 per 1 hour	MM. 58·50 per 1 hour	MM. 58·75 per 1 hour	MM. 59·0 per 1 hour	MM. 59·25 per 1 hour	MM. 59·50 per 1 hour	MM. 59·75 per 1 hour	MM. 60·0 per 1 hour
MM.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.
0·25	0 15·51	0 15·45	0 15·38	0 15·31	0 15·25	0 15·19	0 15·12	0 15·06	0 15
0·50	0 31·03	0 30·90	0 30·77	0 30·63	0 30·50	0 30·38	0 30·25	0 30·12	0 30
0·75	0 46·55	0 46·35	0 46·15	0 45·95	0 45·75	0 45·57	0 45·37	0 45·18	0 45
1	1 02·07	1 01·80	1 01·53	1 01·27	1 01·01	1 00·76	1 00·50	1 00·25	1 0
2	2 04·14	2 03·60	2 03·07	2 02·55	2 02·03	2 01·51	2 01·00	2 00·50	2 0
3	3 06·20	3 05·41	3 04·61	3 03·83	3 03·05	3 02·27	3 01·50	3 00·75	3 0
4	4 08·27	4 07·21	4 06·15	4 05·10	4 04·06	4 03·03	4 02·01	4 01·00	4 0
5	5 10·34	5 09·01	5 07·69	5 06·38	5 05·08	5 03·79	5 02·52	5 01·25	5 0
6	6 12·41	6 10·81	6 09·23	6 07·66	6 06·10	6 04·55	6 03·02	6 01·50	6 0
7	7 14·48	7 12·61	7 10·77	7 08·93	7 07·11	7 05·31	7 03·52	7 01·75	7 0
8	8 16·55	8 14·42	8 12·31	8 10·21	8 08·13	8 06·07	8 04·03	8 02·01	8 0
9	9 18·62	9 16·22	9 13·84	9 11·49	9 09·15	9 06·83	9 04·53	9 02·26	9 0
10	10 20·69	10 18·02	10 15·38	10 12·76	10 10·16	10 07·59	10 05·04	10 02·51	10 0
11	11 22·76	11 19·82	11 16·92	11 14·04	11 11·18	11 08·35	11 05·54	11 02·76	11 0
12	12 24·83	12 21·63	12 18·46	12 15·31	12 12·20	12 09·11	12 06·05	12 03·01	12 0
13	13 26·90	13 23·43	13 20·00	13 16·59	13 13·22	13 09·87	13 06·55	13 03·26	13 0
14	14 28·96	14 25·23	14 21·53	14 17·87	14 14·23	14 10·63	14 07·05	14 03·51	14 0
15	15 31·03	15 27·03	15 23·07	15 19·16	15 15·25	15 11·39	15 07·56	15 03·76	15 0
16	16 33·10	16 28·84	16 24·61	16 20·42	16 16·27	16 12·15	16 08·06	16 04·01	16 0
17	17 35·17	17 30·64	17 26·15	17 21·70	17 17·28	17 12·91	17 08·57	17 04·26	17 0
18	18 37·24	18 32·44	18 27·69	18 22·97	18 18·30	18 13·67	18 09·07	18 04·51	18 0
19	19 39·31	19 34·25	19 29·23	19 24·25	19 19·32	19 14·43	19 09·58	19 04·77	19 0
20	20 41·38	20 36·05	20 30·77	20 25·53	20 20·33	20 15·19	20 10·08	20 05·02	20 0
21	21 43·45	21 37·85	21 32·31	21 26·80	21 21·35	21 15·95	21 10·58	21 05·27	21 0
22	22 45·51	22 39·65	22 33·84	22 28·08	22 22·37	22 16·70	22 11·09	22 05·52	22 0
23	23 47·58	23 41·46	23 35·38	23 29·36	23 23·39	23 17·46	23 11·59	23 05·77	23 0
24	24 49·65	24 43·26	24 36·92	24 30·63	24 24·40	24 18·22	24 12·10	24 06·02	24 0
25	25 51·72	25 45·06	25 38·46	25 31·91	25 25·42	25 18·98	25 12·60	25 06·27	25 0
26	26 53·79	26 46·86	26 40·00	26 33·19	26 26·44	26 19·74	26 13·11	26 06·52	26 0
27	27 55·86	27 48·67	27 41·53	27 34·46	27 27·45	27 20·50	27 13·61	27 03·77	27 0
28	28 57·93	28 50·47	28 43·07	28 35·74	28 28·47	28 21·26	28 14·11	28 07·03	28 0
29	30 00·00	29 52·27	29 44·61	29 37·02	29 29·49	29 22·02	29 14·62	29 07·28	29 0
30	31 02·07	30 54·07	30 46·15	30 38·29	30 30·50	30 22·78	30 15·12	30 07·53	30 0
31	32 04·14	31 55·88	31 47·69	31 39·57	31 31·52	31 23·54	31 15·63	31 07·78	31 0
32	33 06·20	32 57·68	32 49·23	32 40·85	32 32·54	32 24·30	32 16·13	32 08·03	32 0
33	34 08·27	33 59·48	33 50·77	33 42·12	33 33·55	33 25·06	33 16·64	33 08·28	33 0
34	35 10·34	35 01·28	34 52·31	34 43·40	34 34·57	34 25·82	34 17·14	34 08·53	34 0
35	36 12·41	36 03·09	35 53·84	35 44·68	35 35·59	35 26·58	35 17·65	35 08·78	35 0
36	37 14·48	37 04·89	36 55·38	36 45·95	36 36·60	36 27·34	36 18·15	36 09·03	36 0
37	38 16·55	38 06·69	37 56·92	37 47·23	37 37·62	37 28·10	37 18·65	37 09·29	37 0
38	39 18·62	39 08·49	38 58·46	38 48·51	38 38·64	38 28·86	38 19·15	38 09·54	38 0
39	40 20·69	40 10·30	40 00·00	39 49·78	39 39·66	39 29·62	39 19·66	39 09·79	39 0
40	41 22·76	41 12·10	41 01·53	40 51·06	40 40·67	40 30·38	40 20·16	40 10·04	40 0
41	42 24·83	42 13·90	42 03·07	41 52·34	41 41·69	41 31·14	41 20·67	41 10·29	41 0
42	43 26·90	43 15·71	43 04·61	42 53·61	42 42·71	42 31·90	42 21·17	42 10·54	42 0
43	44 28·97	44 17·51	44 06·15	43 54·89	43 43·72	43 32·66	43 21·67	43 10·79	43 0
44	45 31·03	45 19·31	45 07·67	44 56·17	44 44·74	44 33·42	44 22·18	44 11·04	44 0

Distance from Time Mark to some Phase of a Disturbance	INTERVALS BETWEEN TIME MARKS ON A FILM								
	MM. 58·0 per 1 hour	MM. 58·25 per 1 hour	MM. 58·50 per 1 hour	MM. 58·75 per 1 hour	MM. 59·0 per 1 hour	MM. 59·25 per 1 hour	MM. 59·50 per 1 hour	MM. 59·75 per 1 hour	MM. 60·0 per 1 hour
MM.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.	M. S.
45	46 33·10	46 21·11	46 09·23	45 57·44	45 45·76	45 34·18	45 22·68	45 11·29	45 0
46	47 35·17	47 22·92	47 10·77	46 58·72	46 46·78	46 34·94	46 23·19	46 11·54	46 0
47	48 37·24	48 24·72	48 12·31	48 00·00	47 47·79	47 35·70	47 23·69	47 11·79	47 0
48	49 39·31	49 26·52	49 13·84	49 01·27	48 48·81	48 36·45	48 24·20	48 12·05	48 0
49	50 41·38	50 28·32	50 15·38	50 02·55	49 49·82	49 37·21	49 24·70	49 12·30	49 0
50	51 43·45	51 30·13	51 16·92	51 03·83	50 50·84	50 37·97	50 25·21	50 12·55	50 0
51	52 45·51	52 31·93	52 18·46	52 05·10	51 51·86	51 38·73	51 25·71	51 12·80	51 0
52	53 47·58	53 33·73	53 20·00	53 06·38	52 52·88	52 39·49	52 26·22	52 13·05	52 0
53	54 49·65	54 35·53	54 21·53	54 07·66	53 53·89	53 40·25	53 26·72	53 13·30	53 0
54	55 51·72	55 37·34	55 23·07	55 08·93	54 54·91	54 41·01	54 27·22	54 13·55	54 0
55	56 53·79	56 39·14	56 24·61	56 10·21	55 55·93	55 41·77	55 27·73	55 13·80	55 0
56	57 55·86	57 40·94	57 26·15	57 11·49	56 56·94	56 42·53	56 28·23	56 14·06	56 0
57	58 57·93	58 42·74	58 27·69	58 12·76	57 57·96	57 43·29	57 28·74	57 14·31	57 0
58	60 00·00	59 44·55	59 29·23	59 14·04	58 58·98	58 44·05	58 29·24	58 14·56	58 0
58·25	—	60 00·00	60 00·00	—	—	—	—	—	58 15
58·50	—	—	—	—	—	—	—	—	58 30
58·75	—	—	—	60 00·00	—	—	—	—	58 45
59·00	—	—	—	—	60 00·00	59 44·81	59 29·75	59 14·81	59 0
59·25	—	—	—	—	—	60 00·00	—	—	59 15
59·50	—	—	—	—	—	—	60 00·00	—	59 30
59·75	—	—	—	—	—	—	—	60 00·00	59 45
60	—	—	—	—	—	—	—	—	60 00

XII. *Notes on a Visit to Earthquake Observatories in Italy and at Strassburg.* *By* JOHN MILNE.

With the object of more clearly understanding the nature of certain forms of seismographic apparatus referred to or described in various publications, to see instruments and experimental apparatus descriptions of which have yet to be published, to learn something respecting their various degrees of sensibility and their installation, to see the manner in which they are manipulated—which in many instances it is difficult to express in words—and, above all, to make myself acquainted with certain European organisations for the study of movements of the earth's crust, in May of this year I visited seismological observatories and offices at Catania, Cassamicciola, Rome, Rocca di Papa, Padua, and Strassburg.

At these particular stations there exist types of all the most important seismometers, seismographs, and seismoscopes which are at present employed in Europe, and it was for that reason that they were visited.

In the following few notes it is not my intention to describe all that I saw—inasmuch as that would be a repetition of much that is published—but only to say a few words respecting that which was striking and to record general impressions.

CATANIA.—*Gli Osservatorii di Catania e dell'Etna.*
Director, Professor A. RICCO.

For a detailed description of these observatories see 'Memorie della Società degli Spettroscopisti Italiani,' vol. xxvi. 1897.

In 1669 a great part of Catania was destroyed, and 27,000 lives were lost, by an eruption from one of the many parasitic craters which flank the mound-like mass which with its central peak constitutes Etna. One feature of the eruption was a flow of lava which passed over and through the city, and only stopped when it entered the sea. This stream is now patched over with yellow lichen, and along the sides of the railway which passes through it as it enters the city from the north many cuttings in rock and scoria give a good idea of the character of the materials on which Catania and its observatory are founded.

The observatory, which overlooks the city and the sea, stands on the top of one of the steps indicating the contour of the country now buried by the molten flood of 1669.

The buildings are rugged, large, and massive, and apparently form portion of an uncompleted church ; and it is in the spacious vaults of this church (Convento dei Benedettini) beneath the astrophysical observatory that the Seismological Laboratory is established.

The foundations of these buildings, like those of many of the buildings in Catania, follow the very irregular contour of the lava bed from which they rise.

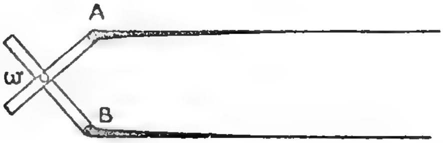
The Instruments.

The entrance to the Physical Observatory on the north side is a hall at the end of which stone stairs lead to upper storeys. In the open space between these there is a thin metal tube reaching from the roof above, and passing downwards through the floor into the vaults beneath. This tube, which is steadied by horizontal wire ties, protects the supporting wire of the great pendulum, which is about 25·3 metres (83 feet) in length. At its upper end it is supported from a double T-iron beam, and at its lower end it carries a cylindrical mass of metal weighing 300 kilos. The bob hangs freely in a case standing on the floor of a special chamber in the crypt-like vaults below.

The movements of the pendulum or of the ground relatively to the same are recorded by pens charged with glycerine ink, somewhat similar to the pens employed in the Richard meteorological instruments, upon a band of paper moving at a rate of one cm. per minute. These pens, which are balanced so that they barely touch the recording surface, are attached to the ends of aluminium levers which multiply the relative motion of the pendulum and the ground 12·5 times. The shorter arms of these levers (A C and B C) are slotted, and embrace the wire of the pendulum, which is 6 mm. thick, just above the bob (fig. 10).

The motion is recorded by suitable levers. At each hour, by means of an electro-magnet in connection with a chronograph, the pens are gently raised from the paper for a period of about six seconds. In this manner time intervals are obtained.

FIG. 10.



Inasmuch as the period of the pendulum relatively to that of local earthquakes is long, it acts as a steady point, and a record of the movements of the ground magnified about 12·5 times is obtained upon the moving band of paper. Two such shocks were recorded on the morning of my arrival in Catania.

With the long-period earthquakes originating at great distances it is assumed that the pendulum follows the slowly tilting ground.

If this is the case, then 1 mm. deflection of the writing indices corresponds to 0·6 sec. of arc.

When the pendulum has given to it a swing with a range of motion as shown by the writing indices of 3·5 cm. after nine complete swings, it comes to rest in 1 min. 42 secs.

The shortness of this interval indicates that in the recording apparatus, especially perhaps with the pens, there is considerable frictional resistance; a feature in the apparatus which I understood Professor Ricco has the intention of improving.

High winds and waves beating on the coast result in a tremulous movement of the writing indices, so that if an earthquake occurred at such a time I presume the rapid movements at its commencement might be eclipsed.

In the centre of a spacious chamber adjoining that in which the large pendulum is installed there is a massive column in the form of a truncated cone, the greatest visible diameter of which is 5 metres. It rises from the floor in the form of a solid circular wall, to the centre of the annular space which this incloses there is an opening. Instruments standing on this can be examined either by walking round the outside or round the inside of this horseshoe-formed pedestal.

At the time of my visit there were standing upon it eight or ten seismoscopes, the microseismoscope of Guzzanti and the seismograph of Brassart.

Amongst the seismoscopes I noted a light spiral spring carrying a weight with a style: if this moved slightly downwards—say less than ·5 mm.—it came in contact with a surface of mercury and closed an electric circuit the time of which might be noted in various manners. The essential feature in two other seismoscopes was a small column standing upon an exceedingly small base. In one instance the column stands freely. To place the column in such a position directly by hand would for many people be almost an impossibility. It is therefore suspended by a collar to hang freely in a tube. When the tube is lowered between guides the bottom of the column comes down upon its base and it remains standing upright.

In another instance the column is brought to a practically upright position by leaning it against a support which by means of a screw is gradually advanced until the column is on the verge of falling. In both cases the columns are in an extremely unstable condition, and, should they fall either by their weight or by making an electric contact, they start a clock or actuate other apparatus which gives the times at which they were disturbed.

The apparatus employed to yield open diagrams of local shocks is a Brassart seismograph. This consists of a pendulum, 3 metres in length, carrying as a bob a ring of metal weighing 26·4 kilos. Embracing a style which projects from the bob downwards are two levers arranged as in the large seismograph. These multiply motion relatively to the pendulum ten times, and their outer ends rest side by side on the surface of smoked glass plate which at the time of an earthquake is set free by electric contact from one of the seismoscopes to run at a rate of about 445 mm. per minute.

The vertical component of motion is obtained either by making a portion of the suspension of the pendulum a spiral spring and treating the heavy bob of the pendulum as a steady point, or from a spring lever seismograph attached to the frame carrying the ordinary pendulum. By a system of levers from the bob of the latter, or from the weighted extremity of the spring lever, a third pointer writes the vertical component of motion side by side with the horizontal components.

I particularly wish to draw attention to this type of instrument, because I found it at several observatories, and it is a type that has evidently found favour in the Italian Peninsula.

For disturbances of short period it has no doubt been found effective, but for the long rolling movements produced by earthquakes originating at distances of 100 or 200 kilometres, when we have periods of from one to four seconds, my own experience is that with such pendulums a more or less violent swinging is established.

The microseismoscope of Guzzanti consists of three inverted pendulums of different periods arranged to make electric contacts. Should they be set in a state of vibration, these contacts are recorded by an electric magnet actuating a pen upon a moving band of paper.

The Cecchi seismograph at Catania, as at other stations I visited, was not in working adjustment, the reason for this being, I presume, that the records from a Brassart type of instrument were found more satisfactory.

Hanging against the wall of the same chamber with the large column is a Bertelli-Rossi tromometer. This consists of a pendulum several metres in length, a style from the bob or plummet of which is viewed by a microscope with a micrometer scale.

Another tromometer is that of Dr. Agamennone. This consists of an ordinary pendulum with a multiplying lever, which actuates two small mirrors, the movement of rays of light reflected from which are recorded on a moving photographic surface.

A very useful apparatus which I found here and at other observatories is the photochronograph of Dr. Cancani.

In a box attached to the wall is a chronometer, above which there is a camera containing a plate and a small electric lamp. At the time of an earthquake one or other of the seismoscopes on the great column make an electric contact, which actuating an electric magnet turns on a current for a second or so to the electric lamp. The result is that the face of the chromometer is photographed. The last piece of apparatus to which my attention was drawn was a tide gauge-like recorder for a well. The bottom of this well is, I understand, in the Pliocene strata beneath the lava on which the observatory is founded. The depth is 32 metres, and is 9·5 metres above sea level. At the time of large earthquakes the puteometric record shows that the water at that depth has been disturbed.

Island of Ischia

Until this year on the island of Ischia there have been two seismological observatories—one at the town of Ischia and the other at Cassamicciola. Dr. Grablovitz, the director of these stations, told me that the former of these was to be abolished, and all the instruments brought together at Cassamicciola. From the jetty at Cassamicciola you see the observatory on the highest portion of a colline some 300 feet above sea level beneath the cliff-faced pinnacles of the extinct Epomeus. On reaching it you look down upon the newly built houses and many ruins, which testify to the disaster of 1883.

The walls of the observatory, like those of the modern buildings, instead of being built of stone and rubble, are of framed timber largely strengthened with iron straps. A few yards distant from the observatory, and in the same garden, is the residence of Dr. Grablovitz and his office.

The observatory is practically a lofty, well-lighted room 30 feet or so in diameter.

In the centre of this there is a massive horseshoe-formed column, on which stand a variety of instruments. On one of the walls is the regulator, which is from time to time corrected by noting the time when a spot of light crosses a meridian line drawn upon the floor. This takes place when the sun passes a slit in the wall in line with the mark upon the floor. Here, as at Catania, there was a three-component Brassart pendulum. Another pendulum had a length of 1 metre, and only records two components of motion, each of which is multiplied ten times.

With apparatus of this description, in which the record is received upon a drum revolving on a horizontal axis, Dr. Grablovitz arranges the pen or style so that it hangs vertically, and therefore comes in contact with the side of the recording surface instead of being, as is usually the case, upon the top of the same. Although in the latter case the pens or styles are balanced, I understood from Dr. Grablovitz that his arrangement, especially when the styles are made of a small thin strip of aluminium, is one that minimises frictional resistance. One apparatus provided with these pens was a pair of horizontal pendulums the lead weights of which were cylinders measuring about 30 cm. by 5 cm. The short arm of these pendulums was 2 cm. and the long arm 40 cm. Quick motion, due to local earthquakes, would therefore be multiplied twenty times. As I saw them they had a period of three or four seconds. If they are to be used to record earthquakes originating at a distance this quantity will be increased; but even then it is doubtful whether they will do more than record the most pronounced portion of such disturbances. This instrument, which is yet in an experimental stage, is the only one I saw whilst in Italy which approximated in its design to modern types of 'steady point' seismographs which have yielded such good results in Japan.

Side by side with these horizontal pendulums were a pair of large astronomical levels, oriented at right angles, cemented to the pier, and covered with glass cases. They are read twice daily.

The next instrument was a pair of conical pendulums, the outer extremities of the booms being so arranged that if they moved to the right or to the left they came in contact with a surface of mercury, completed an electric circuit, and set in action an alarm.

There were also other seismoscopes, but these were not in action.

My attention was next drawn to a model of an astatic suspension, which Dr. Grablovitz hopes to introduce into seismometry. This consisted of a swinging platform carrying an inverted pendulum. By raising or lowering the bob of this pendulum the period of the system is changed, the moment of the platform and that of the loaded mass acting in opposite directions.

In a room outside the main building of the observatory I saw a vasca sismica and a pair of geodynamic levels.

The vasca sismica may be described as a shallow circular tank about 1·5 metre in diameter and 1 metre in depth. Floating on the surface of the water which this contains there is a disc-formed tray nearly filling the whole tank. From two points 90° distant from each other, on the edge of this floating tray, connections are made with the short arms, each 8 mm. in length, of two light levers. The long arms of these levers are 80 cm.

in length, and therefore multiply any motion of the tray nearly 100 times. Their outer ends carry writing points, resting against the face of a drum, driven by clockwork. To prevent these pointers following the same line as the drum revolves a cylindrical sinker is gradually lowered by means of clockwork into the water. The water therefore gradually rises, and with it the floating tray, and the writing levers gradually change their position on the recording surface. The natural period of this tray when set in oscillation is about one second.

The geodynamic levels consist of two zinc tubes, each 2·5 metres in length, terminated at each end with vertical cylinders. These stand on the floor of the room at right angles to each other. On the open ends of these there are floats attached to the short arms (each 8 mm. in length) of levers. The long arm of each lever (80 cm. in length) carries a writing pointer, resting on a recording surface moved by clockwork. The natural period of these water levels is 2·5 seconds.

(For further description in English and reference to original descriptions see Report of the British Association, 1896, p. 226.)

These instruments give an exaggerated representation of the preliminary, and therefore fairly rapid, vibrations of an earthquake originating at a great distance, whilst they show but little of the succeeding slower but larger waves. The general character of their records is therefore the reverse of what is usually obtained from a horizontal pendulum.

The chief instrument at Porto d' Ischia, a few miles distant from Cassamicciola, is a pair of horizontal pendulums. The vertical height of these is 2 metres. The weights, which are 12 kilos., are carried on booms, 10 cm. in length, supported by double ties, one from each side of the weight, but coming together at a point at their attachment above the pivot of the boom. The object of this is to prevent wobbling. The boom is prolonged 80 cm. to its hanging writing point, which rests against a smoked surface of paper moving at a rate of 1 cm. per minute.

Rome.

The Ufficio Centrale Meteorologico e Geodinamico Italiano, which forms portion of the Collegio Romano, is a huge block of buildings surrounded by streets, which stands back about 40 yards from the Corso, one of the principal thoroughfares in Rome. The effect of the traffic is extremely slight, and only occasionally to be observed. Here I met Professor P. Tacchini, the director-in-chief of the meteorological and seismological work of Italy, who very kindly explained the general working of the departments, showed me the instruments, and indicated how I could obtain materials I might require.

One of the upper rooms is devoted to the storing of seismological records and their analysis. When an earthquake occurs in any portion of Italy the observers in the shaken district fill up a postcard-like form and forward the same to this bureau. If the shaking was confined to the island of Sicily, then some thirty of these forms would be received, whilst if it were in the peninsula some hundreds might come in.

A digest of this information, together with many detailed observations from stations provided with seismographs, is from time to time published in the 'Bollettino della Società Sismologica Italiana.' Fuller accounts of observations and instruments appear in the 'Annali dell' Ufficio Centrale Meteorologico e Geodinamico Italiano' (see vol. viii. Part IV. 1886).

Although continuous records of earth movements are made at Rome, the chief work beyond the compilation of the official records is that of testing and experimenting with new forms of apparatus.

The continuous recorders are three pendulums. The larger of these, which is 16 metres in length, and carries a mass of 200 kilos. relatively, to which motion is magnified twelve times, had, I understood, gone to the exhibition in Turin. One which I saw, and known as the Seismometografo Medio, is 8 metres in length, and carries a mass of 100 kilos., with pointers magnifying ten times. These pointers are pens carrying an ink containing much glycerine.

In general form they are like the pens used on the Richard meteorological instruments, but there is some difference in their construction.

They rest upon a band of paper usually moving at a rate of 30 cm. per hour, but at the time of an earthquake, for a period of $1\frac{1}{2}$ minute, this speed is increased to 120 cm. per hour, and until the earthquake ceases this speed is continued.

When the pendulum is caused to swing, so that the writing indices have a range of 2·5 cm., it comes to rest after ten complete oscillations within a period of 11 minutes. The period therefore is a little over one minute ; that is to say, a pendulum with a free period of hardly six seconds is increased to more than sixty seconds in consequence of the damping action of writing indices (?).

This apparatus, together with other instruments, is in the basement of the building, and I understood, like that at Catania, indicates tremors due to wind and occasionally the effects of traffic.

Near to it is a Brassart three-component seismograph, 1·5 metre long, carrying 10 kilos., and multiplying motion ten times.

There were also three seismoscopes : one consisted of a light spiral spring, carrying a weight from which depended a second spiral with a weight, the style of the latter being at rest just above a surface of mercury.

A second seismoscope was a pendulum the style of which hung freely in a small hole in a brass plate. By a slight movement the style comes in contact with the plate, when an electric circuit is completed.

The third seismoscope, designed by Dr. Agamennone, was the most sensitive. It consists of two inverted pendulums having different periods. The upper end of the quicker of the two passes through but without touching the sides of a small hole in a metal plate carried on the slower vibrator. A movement of either results in contact, when an electric circuit actuating a magnet releases the record-receiving surface of a Brassart seismograph, or by some other means records the fact that there has been movement.

Rocca di Papa.

I left Rome to visit Rocca di Papa in company with Dr. A. Cancani, the director of the observatory at that place, and the veteran seismologist Professor M. S. di Rossi. As far as Frascati we travelled by rail, after which came a drive of $1\frac{1}{2}$ hour, when we found ourselves opposite the Albergo Angelletto in Rocca di Papa, some fifteen or twenty miles S.E. from Rome, looking down upon the Campagna. From this point there is yet a steep climb, up streets and lanes through the garden of Professor Rossi, past the caves in which he made his historical tromometrical researches, and then by a zigzag pathway through a wood before the observatory is reached.

At the doorway you stand 760 metres above sea level on a boss of leucite basalt, the nucleus of a once extensive crater. Looking down, you see the roofs and gardens of Rocca di Papa beneath, towards the left is the crater lake of Albano, and towards the right the villages and towns which dot the Campagna, Rome with its St. Peter's, domes and towers, and in the far distance the Mediterranean. There is nothing above you, and you see homesteads and hamlets, with here and there a town below as in a plan.

The first thing to be noticed is that the observatory, although built of stone, is covered with galvanised iron sheets. The object of this is to prevent the absorption of moisture, which in consequence of mist and an annual rainfall, which at this elevation exceeds one metre, would be excessive.

An ascent up a few steps takes the visitor through glass doors, which are opened by a custodian in official uniform, into a lofty, well-lighted octagonally-shaped room about 8 metres in width. From the basement a column of masonry 6 metres in diameter rises up to the floor of this room, where it is continued upwards into the room itself as an annular table about 3 feet in width and 3 feet in height. This, which is faced and covered with white marble, carries about twelve instruments.

In the centre of the annular space a circular column 1·25 metre in diameter rises nearly to the roof of the building. I understood that the object of this was to study the behaviour of certain instruments placed near its top as compared with that of similar instruments placed at lower levels.

At the time of my visit five seismoscopes were installed on small shelves attached round the summit of this shaft. These are electrically connected with a Brassart seismograph, and when one or any of them are agitated the recording surface connected with this apparatus is set in motion. Experience shows that seismoscopes installed upon the top of this elastic column move sooner than similar apparatus placed upon the circular desk.

Hanging round the sides of the column are a series of tromometers, varying in length from about 15 feet to 6 inches (see description of the Catania tromometer). At the present time I believe it is only the longest and shortest of these which are observed, records being taken five times daily.

On the circular table there are a large number of seismoscopes, including the original designs of Professor M. S. di Rossi,[1] Brassart's Seismograph, and the Photo Chronograph of Dr. Cancani.

At this observatory there is another example of the long pendulums. It is 15 metres in length and carries 250 kilos. The multiplication is, as at Catania, 12·5 times, and the record is with ink. On the opposite side of the room and hanging from the wall is a Vicentini pendulum, which will be described with the instruments I saw at Padua.

Among the most striking pieces of apparatus at this observatory are a pair of horizontal pendulums constructed by Dr. Cancani, which of their kind are the largest in existence. The height of the vertical axis is 5·25 metres (17 ft.), and the length of the horizontal boom is 2·7 metres (8 ft. 9 in.). Each pendulum is constructed from two pieces of T-iron brought together and joined to form two sides of a triangle. The free

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[1] See *La Meteorologia Endogena*, vol. ii.

ends of the base, which if joined would form the base of the triangle, are provided with pivots which bear in steel cups.

The plane of the triangular frame is placed parallel to a wall, and its upper pivot hooks into the upper cup, whilst the lower pivot bears directly into the cup near the floor, which has a lateral and fore-and-aft adjustment. On the apex of the swinging triangle a weight of about 25 kilos. is placed. In one case this was pig-iron and in the other a block of marble. Projecting from each apex is a film of glass resting on a drum moving a band of smoked paper at a rate of 60 cm. per hour. At each hour by electrical connections with a chronometer the pointers are lifted for a short interval of time from the recording surface, and time marks are obtained.

At first these pendulums carried pens writing on paper, and it is instructive to notice the great difference in the frictional resistance of these and the ends of rounded glass fibre on smoked paper.

After a deflection of 3 cm. the ink pen continues to move for 12 minutes with a period of 22 seconds, but after a similar deflection with the fibre resting on smoked paper the movement continues for more than one hour, the period being nearly the same.

This apparatus has yielded several instructive diagrams of earthquakes, the most striking of which is that of the Assam earthquake of June 1897.

Whilst examining the seismoscopes Dr. Cancani sketched one of his own, which he considered extremely sensitive. It consists of six inverted elastic pendulums arranged to stand round the circumference of a small circle. Each of these is a vertically placed steel wire the upper end of which is a spiral terminating with a style. These styles are adjusted in close juxtaposition with the edges of a metal disc with which, if they should vibrate, they come in contact. Each of these wires is loaded, but at different heights from their base, with a metal ball, and therefore they have different periods of motion. Contact with the disc completes an electric circuit.

In the Cecchi seismoscope a small column stands freely on a horizontal plate fixed on the top of the style of an inverted pendulum similar to that just described. When this falls, because it is attached by a thread to a catch-controlling clockwork, this catch is released, and the clockwork set in motion.

Padua.

Although the time spent at Padua was, I regret to say, extremely short, in consequence of the kindness of Professor Vicentini and his assistant Dr. Pacher, who had arranged seismograms and apparatus for my inspection, much was learned during the visit. The instruments, which are of the heavy pendulum type, are established on the walls of one of the physical laboratories of the University Buildings, which are surrounded by the traffic of the city. Considering the position in which they are placed on an upper storey, which, as Professor Vicentini remarked, was only occupied from necessity, it is remarkable that so many new and valuable results have been obtained. Although the walls of the University, like most old buildings in Italy, are remarkably solid, they rise from an alluvium foundation, which is very elastic. One result of this is that the movements of the soil due to passing traffic, the ringing of a bell at no great distance, and the pulsations of the ground apparently accompanying fluctuations in barometric pressure at the time of a storm in the distant Alps are all recorded.

Two pendulums which hang side by side had lengths of 1·50 metre, and carried weights of 100 kilos. Side by side with one of these was a bar of steel, about 1·5 metre in length and 10 cm. broad, firmly fixed at one end and bent downwards at the other by a load of 45 kilos. The object of this is to record vertical motion.

The full period of this loaded spring is 1·1 sec. Its outer end is connected by a system of levers with a writing point which rests on a surface of smoked paper side by side with the writing indices of horizontal motion connected with the ordinary pendulum. (For a short description of the ordinary pendulum see British Association Report, 1896, p. 221. For a complete description see 'I Microsismografi dell' Instituto di Fisica della R. Università di Padova:' Dr. Giulio Pacher. Atti del R. Instituto Veneto di Scienze, Lettre ed Arti, tomo viii. serie vii. 1896–97).

In another room there is a similar pendulum, which is, however, 11 metres in length and carries a much heavier load (400 kilos.). In addition to the two systems of levers for horizontal motion, projecting from the bottom of the pendulum is a light pantograph, which gives a resultant motion. The diagram from this latter arrangement is one from which the direction of various vibrations can be easily seen.

The principal feature in the Vicentini and Pacher seismographic arrangements are, first, the large masses that are used as steady points; and secondly, the ingenious and beautiful manner in which movements relatively to these are mechanically magnified and recorded with a minimum of friction. In all instances the magnification is 100-fold. Light levers to magnify movement relatively to an approximately steady mass have been used by Wagner, Gray, Bouquet de la Grye, Agamennone, Brassart, and very many others. I myself have had perhaps 100 pieces of apparatus thus provided, but in no instance when the multiplication exceeded 20 have I been successful—so long as the method was mechanical—to reach conditions so satisfactory as those attained by Vicentini. Rather than multiplying the relative motion of the pendulum by a single lever, Vicentini employs two short levers, each with a multiplication of 10. These are extremely light, balanced, and connected by an ingeniously constructed link (see references mentioned above). The last lever carries a writing index made from a glass fibre. A piece of glass rod is heated by a blowpipe and flattened with pincers. The flattened portion is again heated and drawn out as a long *flat* fibre about 1 mm. broad. This when broken into lengths each of 4 or 5 ins. is sufficient to form several pointers. One of these is taken and one end of it heated and drawn out to still smaller dimensions. The thin end of this is rounded by bringing it for an instant into contact with the edge of a small flame. To attach such a fibre, say, to the end of the boom of a horizontal pendulum this latter is tipped with a fragment of wax. This is heated with a taper and the thick end of the fibre stuck on to the boom.

We may now imagine the fibre to be floating freely as a prolongation of the boom a centimetre or so above the smoked surface on which it is to write. To bring it into contact with this surface a very small flame is placed for a moment beneath the fibre within 3 or 4 cm. of its end, when the rounded point falls upon the smoked surface and is then in adjustment.

For rapid motion the pendulums behave as steady points, and the movements of the ground are multiplied 100 times, whilst for slow movements the angular deflections of the pendulum are similarly enlarged.

The records are received upon a continuous band of smoked paper moving at a rate of 2 cm. per minute. This band hangs vertically, passing over a roller above and round one below. The axes of these two rollers are not parallel, with the result that the paper travels laterally along the upper drum, and the traces drawn by the pens are parallel spiral lines. Every minute, by electrical connections with a clock, time marks are made upon the band. The Vicentini seismographs are now installed at Rocca di Papa, Verona, Siena, and Laibach.

Strassburg.

When I entered the magnificent buildings which constitute the University of Strassburg I felt that I was upon ground which the investigations of the late E. von Rebeur-Paschwitz had made classical. In a few minutes, in company with the genial Professor Gerland and his assistant Dr. R. Ehlert, I was engaged in inspecting seismograms from the Ehlert three-component pendulums. These are recorded on a band of photographic paper, about 21 cm. broad, moving at a rate of 12 cm. per hour. This, with chemicals and other materials, costs about 36*l*. per year. By examining the traces with a magnifying glass, it seems that they consist of a fine series of zigzags, indicating that the pendulums are always in motion. Inasmuch as the removal of the calcium chloride from the pendulum cases does not affect their movements, and because the temperature changes in the chamber where the pendulums are installed is small, it is just possible that these movements may be the result of the city traffic. If this is so, then the movements should be less pronounced at night and more pronounced on public holidays, and at times when traffic is unusually increased. The fact that the tremors produced in a seismograph by a passing carriage or train commence and end suddenly, however, weakens such a supposition.

At present the pendulums are installed on an insulated column in a chamber beneath the Astronomical Observatory (for description of the apparatus see 'Beiträge zur Geophysik,' Band III. Heft 1–3). In the original design of Von Rebeur a complete pendulum weighed 42 gms., and two might be used at right angles to each other.

Each of Dr. Ehlert's pendulums weighs 200 gms., and three are arranged, at angles of 120° with each other, inside a cylindrical iron case. The weights of these pendulums are at their outer ends, near the centre of the casing. By screws from the outside of this case the vertical axes of each of three pendulums can be inclined forwards or laterally. The adjustments, therefore, are not dependent upon screws in a bed plate. The greater weight concentrated at the outer end of each pendulum results in greater certainty of obtaining a steady point for rapid movements of the ground, and hence, perhaps, the continual movement. With three components a direction of motion can be obtained, whilst a very slight movement (the components of which might not be visible on two pendulums) might be recorded on a pendulum to which its direction was nearly at right angles. Each pendulum carries a mirror which reflects a beam of light from a lamp standing near the record-receiving surface 4 metres distant. In front of this there is a cylindrical lens to bring the beams to a focus before impinging on the paper. The clock which drives this band every hour raises a screen which eclipses the beam of light from a fixed mirror in the pendulum case, and in this way gives on the datum line a series of time marks. With a period of 12 seconds one millimetre deflection on the record corresponds to a tilting of $0''\cdot058$.

After visiting the director of the observatory, Professor Becker, who for so many years carried on observations with Von Rebeur's pendulum, Dr. Gerland showed me the site of the Seismological Institute, which next year will be erected within the University grounds. The Government grant for this building is 70,000 marks, or 3,500*l.*, with an annual allowance of 5,500 marks, or 275*l.*, for its maintenance. It is expected that the latter sum will be increased. To commence with, the instruments which it is proposed to instal are Dr. Ehlert's pendulums, a Vicentini pendulum, and a Milne pendulum similar to those established by the B.A. Committee.

As a correction and extension of the second and third paragraphs of the Report of 1897, p. 129, I learned from Dr. G. Gerland that the idea of an international organisation for the observation of earthquakes was first brought forward by the late Dr. E. von Rebeur-Paschwitz and himself in October 1894. At the end of 1894 and the beginning of 1895 they prepared a definite appeal to the scientific world to carry out their suggestions: this appeal, written by Dr. von Rebeur, was subscribed by a series of prominent learned men and was published in the 'Beiträge zur Geophysik,' edited by Professor Gerland, Band II. p. 773.

After the death of Dr. von Rebeur Dr. Gerland naturally felt pledged to continue the work which he had co-operated to inaugurate. Subsequent issues of the propositions therefore appeared under the name of Dr. Gerland, who in 1895 brought the same to the notice of the International Geographical Congress in London.

Briefly stated, they were to establish a centre for the collection and publication of reports relating to *all* earthquakes which are from time to time recorded throughout the world.

It was proposed to issue these reports in Dr. Gerland's geophysical journal.

The most important records would be those obtained from horizontal pendulums, ordinary long pendulums, and bifilar pendulums, and as a commencement it was suggested that ten observing stations should be established round the world.

The positions of these stations were chosen with regard to Japan, from which country large earthquakes frequently radiate.

The Congress passed a resolution respecting the desirability of carrying out Dr. Gerland's proposal.

Very shortly we may expect to see the publication of the first part of the great work which Dr. Gerland has undertaken, in connection with which the reports issued by this committee will undoubtedly prove an assistance.

CONCLUSION.

In connection with the instruments which I saw in Italy and at Strassburg, I will first consider those which are employed to record local disturbances or the short-period movements which we can feel.

In Japan I once used a pendulum carrying 80 lb., and 40 feet in length; two pendulums, each of which carried 32 lb., and were 36 feet in length, and very many 3 or 4 feet in length, carrying heavy disc-like bobs.

Some of these recorded by light pointers resting on stationary or moving smoked-glass surfaces, whilst others recorded the relative motion of the pendulum with similar pointers attached to the end of light levers, which multiplied the movements of the pendulums.

Professor J. A. Ewing established in Japan a heavy pendulum 20 feet in length, the movements of which relatively to the ground were recorded as two components by means of short levers.

The result of our experience with these instruments, which extended over several years, was that, although they occasionally yielded useful diagrams of local disturbances, it so often happened that an earthquake took place which had a period approximately agreeing with the natural period of the pendulums that these were set in violent motion.

Inasmuch as the period of local earthquakes is for the most part less than three seconds, whilst the period of the long pendulum at Catania is ten seconds, the bob of this instrument becomes a practically steady point for such disturbances.

Directly, however, we turn to the pendulums one or two metres in length which we find so largely employed in the Italian Peninsula, it seems impossible that the character of the seismograms of local shocks which they furnish should not be largely affected by the free period of these instruments.

I—and I think I may add all observers who have had experience with the ordinary pendulum type of apparatus, and also with the long-period duplex pendulums and the steady point bracket seismograph used in Japan, not only in recording actual earthquakes, but also in testing such instruments by subjecting them to artificially produced earthquake-like movements, which movements were absolutely measurable—would not hesitate in adopting the two latter types of apparatus in preference to those in which the principal feature is the bob of an ordinary free pendulum.

Directly we turn to a consideration of the form of apparatus best adapted to record the movements due to earthquakes which have originated at great distances we are upon uncertain ground.

What is chiefly required is to determine the time at which a movement commences, the duration of its various phases, and to measure its varying amplitudes, periods, and directions.

A source of error, especially with regard to the measurement of amplitude or angular motion, rests in the fact that the periods of various phases of earthquake motion may vary between as much as five and sixty seconds. The consequence of this is that at some time or other there is synchronism between the natural period of the instrument and that of its moving platform, with the result that records may be greatly distorted.

A good illustration of the difference in records obtained from different instruments is seen when we compare the records of horizontal pendulums and those of the vasca sismica (see p. 263).

Dr. Cancani's observations on the great Indian earthquake of 1896 (p. 207) also show the amount of difference which may be expected in seismograms obtained from pendulums varying in period.

From what we know at present, seismograms which are trustworthy in their main features are yielded by apparatus which for rapid preliminary tremors records the same relatively to a steady point; and if the pendulum has a natural period of ten to fifteen seconds it apparently follows the slow movement of the succeeding waves.

To extend our knowledge on this subject a central station might be provided with a number of instruments having different periodic motion. Inasmuch as very long pendulums, as at Catania, shorter pendulums or horizontal pendulums with a high multiplication, as at Padua and Strassburg, are affected by wind and other activities disturbing their supports, which at the latter place result in what appears to be continuous movement, it is likely, and in some instances it is certain, that the preliminary tremors of an earthquake have been eclipsed, and its commencement therefore been rendered uncertain.

The general direction in which motion has advanced is known from the time records obtained at several stations. The varying directions at which the ground has moved at a given station may from an instrument recording movements as two rectangular components be sometimes determinable. Usually, however, we are left to choose between two directions.

The records from Dr. Ehlert's pendulum and the apparatus of Vicentini remove such doubts.

As to whether a seismogram can or cannot be analysed with regard to the period and amplitude of separate waves simply depends upon the speed at which the record-receiving surface is moved.

Contrasting the various types of instruments last referred to with the type of instrument adopted by this committee, considering the object in view, there does not appear to be any necessity to regret the choice which they have made.

Each instrument has its merits, and for particular purposes may be better than any other. It was impossible for the committee to have adopted either the long pendulums or large horizontal pendulum of Italy on account of the difficulty of their installation. The Strassburg pendulums, although most desirable at a central station, require a too carefully insulated installation, and entail too much expense for photographic materials to put them within the reach of ordinary observers.

Like the Ehlert pendulums, another instrument equally desirable at a central station is the Vicentini pendulum. However, as this requires the addition of a chronometer and delicate manipulation to insure similarity in adjustment, and a somewhat high and solid supporting wall or pier, it is likely that private observers might find difficulty in its adoption.

For further information respecting the various types of seismographs here mentioned the reader is referred to the British Association Report for 1896, p. 182.

From the preceding notes it is clear that in Italy and Germany seismological investigation receives substantial recognition.

For many years past in the former of these countries observatories have been established, at each of which we find a resident observer, his assistant and custodian with their necessary dwellings, offices, and workrooms. When first established the object of these institutions was to record and study the more or less violent movements of the earthy crust which can be felt. To this was added the observation of the ubiquitous so-called earth tremors, and partly, perhaps, because it was found that these latter in particular were closely associated with certain meteorological conditions, the system was incorporated with the Meteorological Bureau.

During the last few years the observations have been extended to embrace those of movements due to earthquakes which originated at great distances. These unfelt movements of the earth's crust, which are as frequent in Great Britain as they are in the Italian Peninsula, are those which at present receive the greatest attention.

It has no doubt been largely due to the discovery that earthquakes can be recorded in any one country as well as in any other that the German Government has been led to devote so large a sum for the establishment of a central observing station in Strassburg, and at the University of Göttingen provision has been made for a professorship of earth physics.

In Austria, for some time past, the Kaiserliche Akademie der Wissenschaften has had its earthquake commission, which has issued publications and established several earthquake stations provided with the Rebeur-Ehlert pendulums.

The Central Observatorium of St. Petersburg has established several stations somewhat similar to those in Austria, and in both countries the means for observing especially the unfelt earthquakes is being extended.

The elaborate system of earthquake observation which has been in existence for many years in Japan is too well known to require description. This is now being extended to embrace observations on earth movements not recordable by ordinary seismographs. In addition to the bureau which reports upon ordinary earthquakes, which forms portion of the meteorological department and a chair of seismology at the University, there is a large committee composed of practical engineers and others whose chief work it is to carry out investigations which may lead to the mitigation of earthquake effects. In connection with the first year's work of this committee the Government grant was 5,000*l.* Inasmuch as practical results have been obtained from this committee every year, I believe a substantial sum of 1,000*l.* or 2,000*l.* appears in the Parliamentary estimates for a continuation of their investigations.

It will no doubt be of interest to this committee to note that means which experience has demonstrated lead to the mitigation of earthquake effects, have during the past year received the consideration of the English Government and private companies in connection with reconstruction after severe earthquakes in the West Indies and Assam.

The inauguration of the investigations which led to the demonstration of these means was in great measure due to the support which this Association has from time to time given to their committees.

XIII. *Preliminary Examination of Photograms obtained with the Seismometer in the Liverpool Observatory.* *By* W. E. PLUMMER.

In August 1897 the Seismological Committee of the British Association entrusted one of their seismometers to my care. It was mounted by Mr. Horace Darwin in a cellar of the Observatory, and the photographic record of the motion of a spot reflected from the mirror has been maintained since, save for a few interruptions arising from the failure of the clock or some temporary disturbance. The instrument itself has been described by Dr. Davison in 'Nature,' l. 246, and the general arrangement of the apparatus there detailed, the method of determining the scale, and the directions for the use of the instrument, have been followed without alteration at the Liverpool Observatory. The instrument is arranged to measure tilts or displacements in the plane of the prime vertical: the mirror being in this plane, that of the suspending wires being at right angles. Disturbances are shown by the motion of a spot of light being carried to the east or west of its normal position. The more noticeable deviations from uniformity have been reported to Professor J. Milne as produced probably by earthquake shocks; the dates of these interruptions appear in another part of the report. The instrument, however, does not seem very well adapted for the measurement and discussion of these irregular motions. Some difficulty arises from the smallness of the time scale (10 m.m. of paper passing in an hour), in consequence of which small rapid vibrations are indistinguishable, while the sensitiveness of the instrument as at present used does not seem to be sufficiently great to record the characteristic motion. In Dr. Davison's instrument a displacement of the spot of light through 3·44 inches corresponded to a tilt of the mirror of one second of arc. I endeavoured at first to reach this degree of sensitiveness, and met with difficulties, some of which will be mentioned later. But a recommendation was sent to me last May by Professor Milne to so arrange the instrument that a tilt of the ground of two seconds should move the spot of light on the scale 1·74 inch. I have endeavoured to conform to this direction with the result that the instrument appears more stable, and the trace produced on the sensitised paper seems still more adapted to the discussion of the bending of the earth's crust throughout considerable periods of time than for the observation of the pulsations produced by irregular and violent shocks. The following discussion is therefore confined entirely to the uniform behaviour of the spot of light.

For a very considerable time after the instrument was mounted the photographic trace showed such a continual and rapid motion towards the east that all other effects were completely masked. This was no doubt due to a want of stability in the steel rod carrying the instrument, which had not yet come to a position of rest. The frequent alteration of the foot-screws, always in one direction, necessary to bring the spot of light back on the scale, disturbed the level to such an extent that the sensitiveness varied considerably. This was no doubt assisted by a motion of the rod in the plane of the meridian, which would alter the horizontal distance between the points of suspension of the wire carrying the mirror: a motion which would not be visible on the photographed trace. About November the constant motion of the mirror became less recognisable, and the series of measures here described was begun in January of this year, at which time it is hoped the instrument had settled into its normal conditions. The scale for converting the linear displacement of the photographic trace into seconds of arc still continues, however, to give some trouble, and this feared irregularity in the scale has prevented the use of many of the records in the following discussion. The scale, it may be as well to explain, is determined by turning the mirror through a known angle by means of a rocking-arm, capable of being moved from a distance by the alternate inflation of one or other of two india-rubber balls. It has been the rule to move this rocking-arm once a day, and those records are considered trustworthy when the linear displacement of the light is the same at the beginning and end of the day. When the displacement is not accordant there seems to be no way of making the observations available for discussion. Moreover, it is found practically that very different intervals of time are required to bring the mirror to a state of rest. Sometimes the motion goes on for three or four hours after the initial disturbance, usually much less. I can offer no explanation of these anomalies. I merely mention them here to show that the amount of material at my disposal is not so great as I could wish: that a much longer time is necessary to remove the instrumental and systematic errors, and that the present result is a preliminary inquiry now offered to show what use has been made of the instrument entrusted to my care.

However distrustful one may be of the result, and however cautiously one may feel it necessary to speak of the numerical values obtained, it is impossible to doubt the general character of the motion of the mirror, notwithstanding the small angles with which we have to deal. A mere glance at the record for any one day is sufficient to show the general features of the curve, and herein I believe the motion in the prime vertical agrees with that derived from meridional displacement, though to what extent the motion precedes or follows that on the meridian I have no data to offer. On all days on which the photographic trace has offered no suspicion of unsteadiness in the scale value, or where no interruption of the trace has been made for more than twenty-four hours, the ordinates of the curve have been measured from the time traced for each hour. These ordinates have been read off to the tenth of a millimetre, corresponding usually to about 0·004 of a second of arc, consequently the third place of decimals has been retained, but simply as a matter of calculation. These measures have been grouped in monthly periods, for it was soon apparent that the time of maximum displacement was not constant throughout the year. The mean values of the ordinates for each month have been compared with Bessel's Interpolation Equation for expressing in the usual periodic formulæ the reading at any hour of the day, reckoned from noon, in terms of the mean value and the hour of the day. Supposing the general expression for the value of the measured ordinates at the hour $\frac{n}{15}$ after noon to be represented by the formula

$$D_x = D + a\sin(x + A) + b\sin(2x + B) + c\sin(3x + C),$$

the following table will give the value of the constants D, a, b, c, A, B, C, derived from the solution of the equations formed by the substitution of the mean monthly ordinates for every two hours in the general expression:—

TABLE I.

Month	D	a	b	c	A	B	C
	″	″	″	″	° ′	° ′	° ′
January . .	0·000	0·0194	0·0421	0·0145	8 5	270 29	65 30
February . .	− ·005	·0281	·0457	·0143	4 54	257 53	358 2
March . .	+ ·001	·0292	·0529	·0092	32 11	285 30	142 11
April . .	− ·004	·0264	·0496	·0079	30 50	322 16	196 30
May . . .	− ·011	·0185	·0572	·0046	45 0	309 30	278 51
June . .	− ·008	·0363	·0583	·0170	92 32	287 9	29 27
July . . .	− ·003	·0527	·0483	·0074	112 17	343 17	72 33
August . .	− ·003	·0136	·0670	·0069	118 36	283 33	288 11

The principal maximum values, both positive and negative, for each month as derived from the forementioned equation are as follows:—

TABLE II.

Month	Time of Maximum Displacement	Amplitude	Month	Time of Maximum Displacement	Amplitude
	H. M.	″		H. M.	″
January .	6 17 P.M.	+0·0603	May . .	4 27 P.M.	+0·0781
„ .	0 34 A.M.	− ·0602	„ . .	10 55 „	− ·0635
„ .	5 24 „	+ ·0323	„ . .	5 1 A.M.	+ ·0377
„ .	10 21 „	− ·0353	„ . .	10 34 „	− ·0524
February .	6 34 P.M.	+ ·0597	June . .	4 10 P.M.	+ ·0516
„ .	1 26 A.M.	− ·0645	„ . .	0 3 A.M.	− ·1006
„ .	6 15 „	+ ·0319	„ . .	5 48 „	+ ·0735
„ .	11 4 „	− ·0497	„ . .	10 30 „	− ·0279
March . .	5 48 P.M.	+ ·0841	July . .	3 20 P.M.	+ ·0690
„ . .	11 32 „	− ·0732	„ . .	9 36 „	− ·1038
„ . .	5 27 A.M.	+ ·0221	„ . .	4 38 A.M.	+ ·0351
„ . .	11 5 „	− ·0337	„ . .	10 8 „	+ ·0048
April . .	4 31 P.M.	+ ·0803	August . .	4 57 P.M.	+ ·0642
„ . .	10 30 „	− ·0592	„ . .	11 24 „	− ·0727
„ . .	3 43 A.M.	+ ·0210	„ . .	5 57 A.M.	+ ·0738
„ . .	9 36 „	− ·0412	„ . .	11 32 „	− ·0612

TABLE III.

	January	February	March	April	May	June	July	August
Noon	−0″·005	+0″·009	−0″·001	+0″·011	+0″·001	+0″·019	−0″·017	−0″·014
1 P.M.	− ·003	− ·006	+ ·017	− ·002	+ ·011	+ ·004	+ ·019	− ·012
2 „	− ·007	− ·008	− ·013	− ·004	− ·011	− ·008	+ ·004	+ ·003
3 „	+ ·017	− ·012	− ·006	+ ·017	− ·008	− ·010	− ·021	+ ·011
4 „	− ·003	+ ·013	·000	− ·005	+ ·010	+ ·005	− ·014	+ ·018
5 „	+ ·006	+ ·005	+ ·022	− ·003	− ·019	+ ·013	− ·005	+ ·016
6 „	+ ·003	+ ·014	+ ·013	− ·010	− ·001	− ·005	+ ·006	− ·007
7 „	− ·019	− ·001	− ·011	·000	+ ·013	− ·015	− ·001	− ·014
8 „	+ ·010	− ·014	− ·017	+ ·006	+ ·005	+ ·009	+ ·001	− ·017
9 „	+ ·006	+ ·001	− ·020	+ ·022	+ ·003	+ ·001	− ·001	− ·019
10 „	+ ·005	+ ·013	+ ·003	+ ·012	− ·024	+ ·004	+ ·001	+ ·008
11 „	·000	− ·002	+ ·007	+ ·003	− ·009	− ·010	·000	+ ·006
Midnt.	− ·009	− ·015	− ·004	− ·017	− ·011	− ·005	− ·001	+ ·019
1 A.M.	+ ·021	+ ·003	+ ·002	− ·006	+ ·008	+ ·019	·000	− ·002
2 „	− ·002	− ·002	− ·011	+ ·002	− ·008	− ·006	− ·009	+ ·007
3 „	+ ·003	− ·001	− ·019	− ·019	− ·006	− ·008	+ ·015	+ ·005
4 „	+ ·005	+ ·013	+ ·016	− ·014	+ ·006	+ ·008	− ·003	− ·022
5 „	− ·013	− ·008	+ ·010	+ ·001	− ·006	− ·019	·000	+ ·005
6 „	+ ·003	+ ·021	− ·003	− ·007	+ ·014	− ·013	− ·001	+ ·021
7 „	− ·019	+ ·002	− ·001	+ ·003	+ ·025	+ ·017	+ ·009	− ·011
8 „	− ·007	− ·002	+ ·004	− ·014	− ·001	− ·014	+ ·006	− ·010
9 „	+ ·006	+ ·002	+ ·014	− ·016	+ ·012	+ ·001	+ ·016	+ ·013
10 „	− ·008	+ ·007	− ·016	+ ·022	+ ·007	− ·001	− ·007	− ·003
11 „	− ·010	− ·006	− ·008	+ ·009	− ·002	− ·005	− ·019	+ ·007

The meaning of the positive sign in Table II. and elsewhere is that the spot of light has travelled towards the east. So far as Table II. shows anything, it exhibits a tendency for the first eastern elongation, that in the afternoon, to occur earlier in the day as the year advances, also that the amplitude of the afternoon excursion, whether east or west, is greater than that in the morning, and that the maximum effect occurs in the summer months. It would be wrong to insist too strongly even on these tendencies considering that only a part of one year has been examined, and certainly premature to suggest any physical interpretation. I hope, however, that this partial result may prove of sufficient interest to induce the Committee to sanction further inquiries of the same nature, for which I think the instrument is peculiarly well fitted. Lastly, I give in a tabular form (Table III.) the difference (C—O) between the mean monthly result at each hour of the day, derived from the photograms, and the values computed from the interpolation equation.

XIV. *Reports on Seismological Investigations published by the British Association.*

		PAGE
1841.	Report on Instruments to record Earthquakes in Scotland and Ireland. Drawn up by Lord GREENOCK and DAVID MILNE	46–50
1842.	Report on Registering Shocks of Earthquakes in Great Britain. By DAVID MILNE	92–98
1843.	Report on Registering Shocks of Earthquakes. WM. BUCKLAND, DAVID MILNE	120–127
1844.	Report on Earthquake Shocks in Scotland. DAVID MILNE	85–90
1847.	Report on Geological Theories of Elevation and Earthquakes. WILLIAM HOPKINS, M.A., F.R.S.	33–92
1850.	First Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S.	1–89
1851.	Second Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S.	272–320
1852.	Third Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S.	1–176
1854.	Third Report (continued) on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S.	1–326
1854.	Report on Earthquakes and Seismometers. Col. PORTLOCK, R.E., F.R.S.	370–372
1858.	Fourth Report on the Facts of Earthquake Phenomena. ROBERT MALLET, C.E., F.R.S.	1–136
1861.	Experiments at Holyhead on the Transit Velocity of Waves analogous to Earthquake Waves. ROBERT MALLET, C.E., F.R.S.	201–236

Reports on the Earthquake Phenomena of Japan, drawn up by John Milne, were issued, under varying titles, yearly from 1881 until 1895.

In 1895 the 'Earth Tremor' Committee, appointed to investigate earth tremors in Great Britain, issued the last of a series of Reports dated 1893, 1894, and 1895, the Secretary being Mr. C. Davison.

In 1896 Committees on the Earthquake Phenomena of Japan and Earth Tremors were united under the joint secretaryship of C. Davison and J. Milne for the purpose of carrying on seismological investigation, and have issued their First, Second, and Third Reports.

The British Association has issued since 1841 about thirty-seven Reports relating to earthquakes.

Meteorological Observations of Ben Nevis.—Report of the Committee, consisting of Lord McLaren, Professor A. Crum Brown (*Secretary*), Sir John Murray, Dr. Alexander Buchan, *and* Professor Copeland. (*Drawn up by* Dr. Buchan.)

The Committee was appointed, as in former years, for the purpose of cooperating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations by night as well as by day, which are a specialty of the Ben Nevis Observatory, were made with complete regularity during the year 1897 by Mr. Angus Rankin, the superintendent, and his assistants. The Directors of the Observatories tender their best thanks to Messrs. T. S. Muir, A. Drysdale, M.A., B.Sc., John S. Begg, T. G. Kay, D. Macrae Aitken, A. Aitken, George Ednie, and T. Kilgour for the invaluable help they have rendered as volunteer observers during the past year, by which the much-needed relief has been given to the members of the regular staff. In addition to this, Messrs. Muir and Drysdale have given much time and labour in discussing, under the superintendence of the Directors, the observations made in the summer months at the intermediate station, together with the observations at the two Observatories at the same time, in connection with the weather which prevailed at the time, more especially the anticyclones and the cyclones which occurred. The result, which the Directors consider to be of considerable value, will be referred to in a subsequent part of this report.

Table I. shows for 1897 the mean monthly and extreme pressures and temperatures; amounts of rainfall, with the number of days of rain, and the days on which the amount equalled or exceeded one inch; the hours of sunshine; the mean percentage of cloud; the mean velocity of the wind in miles per hour at the top of the mountain; and the mean rainband at both Observatories. The mean barometric pressures at Fort William Observatory are reduced to 32° and sea-level, but those at the Ben Nevis Observatory only to 32°.

Table I.

1897	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·255	25·285	24·889	25·199	25·350	25·482	25·463	25·229	25·356	25·504	25·479	25·090	25·298
Fort William	29·937	29·902	29·453	29·800	29·917	29·986	29·927	29·657	29·885	30·057	30·072	29·661	29·855
Differences .	4·682	4·617	4·564	4·601	4·567	4·504	4·464	4·428	4·529	4·553	4·593	4·571	4·557
Mean Temperatures.													
Ben Nevis Observatory	20°·0	26°·3	24°·5	25°·4	32°·3	40°·2	45°·1	42°·8	35°·1	36°·3	33°·6	27°·3	32°·4
Fort William	35·7	40·5	41·6	43·3	48·1	55·1	58·5	58·7	51·0	48·8	45·6	39·6	47·2
Differences .	15·7	14·2	17·1	17·9	15·8	14·9	13·4	15·9	15·9	12·5	12·0	12·3	14·8
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	31°·1	37°·3	36°·4	37°·8	48°·3	58°·0	64°·0	60°·2	48°·3	52°·6	52°·0	39°·4	64°·0
Fort William	51·0	54·5	52·7	60·1	70·6	77·1	80·4	77·0	67·6	61·9	57·8	54·9	80·4
Differences .	19·9	17·2	16·3	22·3	22·3	19·1	16·4	16·8	19·3	9·3	5·8	15·5	16·4

TABLE I.—*continued.*

1897	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Extremes of Temperature, Minima.													
Ben Nevis Observatory	4°·0	12°·7	10°·2	11°·3	16°·9	24°·7	29°·0	33°·7	25°·0	17°·6	13°·0	17°·0	4°·0
Fort William	24·3	25·6	26·3	27·2	30·8	40·9	41·1	43·4	34·8	28·8	26·2	21·9	21·9
Differences .	20·3	12·9	16·1	15·9	13·9	16·2	12·1	9·7	9·8	11·2	13·2	4·9	17·9
Rainfall, in Inches.													
Ben Nevis Observatory	3·42	16·22	17·24	6·55	10·91	8·46	14·13	11·88	17·04	12·08	17·78	20·07	155·78
Fort William	1·67	8·06	8·47	4·24	4·79	4·12	6·93	5·24	9·75	6·28	6·50	11·79	77·84
Differences .	1·75	8·16	8·77	2·31	6·12	4·34	7·20	6·64	7·29	5·80	11·28	8·28	77·94
Number of Days 1 in. or more fell.													
Ben Nevis Observatory	0	5	5	0	3	2	6	2	7	4	8	7	49
Fort William	0	1	1	0	1	0	1	1	4	1	1	3	14
Differences .	0	4	4	0	2	2	5	1	3	3	7	4	35
Number of Days 0·01 in. or more fell.													
Ben Nevis Observatory	16	16	23	17	18	18	18	23	26	20	20	23	238
Fort William	14	20	25	14	19	19	18	23	22	17	20	23	234
Differences .	2	−4	−2	3	−1	−1	0	0	4	3	0	0	4
Mean Rainband (scale 0–8).													
Ben Nevis Observatory	1·0	2·7	2·6	2·1	2·0	1·2	2·3	2·4	2·7	1·7	2·0	2·3	2·1
Fort William	2·1	2·8	4·3	3·3	3·1	3·8	3·1	3·7	4·2	3·6	3·6	3·6	3·4
Differences .	1·1	·1	1·7	1·2	1·1	2·6	·8	1·3	1·5	1·9	1·6	1·3	1·3
Number of Hours of Bright Sunshine.													
Ben Nevis Observatory	22	22	21	98	159	77	170	35	87	80	43	27	841
Fort William	40	27	59	158	200	139	188	107	112	94	38	22	1,184
Differences .	18	5	38	60	41	62	18	72	25	14	−5	−·5	343
Mean Hourly Velocity of Wind, in Miles.													
Ben Nevis Observatory	22	18	23	14	14	13	12	13	12	20	13	18	16
Percentage of Cloud.													
Ben Nevis Observatory	89	88	95	79	71	89	72	92	87	73	82	89	84
Fort William	69	79	79	62	60	79	68	76	70	60	77	71	71
Differences .	20	9	16	17	11	10	4	16	17	13	5	18	13

At Fort William the mean atmospheric pressure for the year was 29·855 inches, being 0·011 inch higher than the average of the forty years, 1856–95. The mean at the top of Ben Nevis, reduced to 32° only, was 25·298 inches, and was nearly the average of the observations made since the opening of the Observatory in December 1883. The difference for the two Observatories was thus 4·557 inches for the year, being nearly the average difference of past years. At the top of the mountain the absolute highest pressure for the year was 26·029 inches in September; and at Fort William 30·584 inches in December.

The differences from the mean monthly pressure very greatly exceeded the averages in October and November, the excesses respectively being for Fort William 0·278 inch and 0·280 inch, and at the top of Ben Nevis 0·234 inch and 0·242 inch. The evidently anticyclonic character of the weather of these two months is well shown by the mean temperatures of the two Observatories, thus :—

	Fort William.	Ben Nevis Observatory.
	°	°
Change from September to October	−2·2	+1·2
„ „ October to November	−3·2	−2·7
„ „ September to November	−5·4	−1·5

On the other hand, when the weather is strongly cyclonic, the reverse holds good. Thus in March the mean pressure was 0·300 inch under the average of March, the weather being decidedly cyclonic, when the change of temperature from February to March was +1°·1 at Fort William, but −1°·8 at the top of the mountain.

The following shows the deviations of the mean temperature of the months from their respective averages :—

	Fort William.	Top of Ben Nevis.	Difference.
	°	°	°
January	−3·5	−3·8	−0·3
February	1·4	2·4	1·0
March	1·5	0·7	−0·8
April	−2·2	−2·1	0·1
May	−1·9	−0·5	1·4
June	−0·6	1·3	1·9
July	1·2	4·8	3·6
August	1·2	2·9	1·7
September	−2·3	−2·8	−0·5
October	1·2	5·0	3·8
November	3·8	5·6	1·8
December	−0·3	2·3	2·6
Year	0·0	1·0	1·0

Hence, owing to the frequent occurrence of well-marked and long-continued anticyclones, the mean annual temperature at the top of the mountain was relatively one degree higher than that of Fort William; and the differences of the means of some of the months—notably of July and October—were very striking.

The absolutely highest temperature for the year recorded for Fort William was 80°·4 on July 15, and at the top 64°·0 on July 16. The absolutely lowest temperature was 20°·0 at Fort William on December 23, and at the top 4°·0 on January 25. The most noticeable feature of the extreme temperatures at the top is the high extremes during October and November when the anticyclonic type of weather was predominant. In November, temperature rose on the 4th to 52°·0, being higher than that recorded in any previous November.

As regards the extremes of temperature, the difference between the two maxima was greatest in April and May, when it was 22°·3, and least in October and November, when it was respectively 9°·3 and 5°·8; and the difference between the two minima greatest in January, when it was 20°·3, and least in December, when it was only 4°·9.

The registration of the sunshine recorder at the top shows 813 hours out of a possible 4,470 hours, being 118 hours more than in 1895, and 57 hours more than in 1896. This number of 813 hours is greater than any annual amount recorded since 1891, but is 157 hours fewer than in 1888, when the hours of sunshine numbered 970. The number 813 is 18 per cent. of the possible sunshine. The maximum was 170 hours in July, and the minimum 21 hours in March, these being respectively the absolutely largest and the smallest numbers of hours of sunshine recorded in any previous July and March. At Fort William the number of hours for the year was 1,184, being the largest annual number recorded since 1891, when the number was 1,220 hours. The maximum was 200 hours in May, and the minimum 22 hours in December. As regards the 22 hours in December, this number is larger than that of previous Decembers since 1890. The annual number of hours, 1,184, at Fort William is 34 per cent. of the possible sunshine there.

In the subjoined Table II. there are given for each month the lowest observed hygrometric readings:—

TABLE II.

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°	°	°	°	°	°	°	°	°	°	°	°
Dry Bulb .	25·7	26·0	23·9	29·2	39·8	47·9	52·7	51·0	31·3	48·5	49·6	28·9
Wet Bulb . .	18·8	19·1	21·9	21·8	27·1	36·8	36·8	38·9	27·5	34·9	34·9	20·8
Dew-point . .	–17·8	–16·1	9·9	–4·1	10·6	23·3	10·3	26·8	17·4	19·9	18·7	–8·8
Elastic Force . .	·018	·020	·067	·036	·069	·125	·104	·146	·095	·107	·101	·028
Relative Humidity (Sat.=100)	13	14	52	22	28	37	26	39	55	31	28	18
Day of Month .	20	12	5	22	20	4	13	2	9	25	4	22
Hour of Day . .	Midn.	7 a.m.	10 a.m.	7 a.m.	4 a.m.	3 a.m.	8 a.m.	10 p.m.	9 a.m.	11 a.m.	10 a.m.	3 a.m.

Of these lowest monthly humidities, the lowest occurred in January, when the dew-point was –17°·8; the elastic force of vapour ·018 inch, and relative humidity 13. Very low humidities also were recorded in February and in December. Just as happened in the previous year, no very low humidity occurred in September, the lowest relative humidity being 55.

At the Ben Nevis Observatory the mean percentage of cloud was 84, which is nearly the average, the maximum being 95 in March and the minimum 70 in November; and at Fort William the mean was 71, the maximum being 78 in November and the minimum 60 in May.

The mean rainband (scale 0–8) observations at the top was 2·1 for the year, the maximum being 2·7 in September and the minimum 1·0 in January. At Fort William the mean for the year was 3·4, the maximum being 4·3 in March and the minimum 2·1 in January.

The mean hourly velocity of the wind at the top of Ben Nevis was 16 miles per hour, being the highest since 1891; the maximum velocity was 23 miles in March, and in January the number was 22 miles. The lowest velocity was 12 miles in July and again in September, this being the lowest minimum hitherto recorded in any previous year.

The rainfall for the year was 154·76 inches, or fully 6 per cent. above the average. The previous large annual rainfalls exceeding the above were 197·95 inches in 1890, 178·74 inches in 1891, and 165·77 inches in 1893. The largest monthly amount was 20·07 inches in December, and the smallest 3·42 inches in January, or only 22 per cent. of the average rainfall of the month. The heaviest fall on any single day was 4·52 inches on the 25th of February.

At the top of the mountain rain fell on 238 days, and at Fort William on 234 days, these being respectively twenty-two days and four days under the averages. At the top the maximum number of rainy days was

26 in September, and at Fort William twenty-four in March, and the minimum number sixteen in January and again in February at the top, and fifteen in April at Fort William.

During the year the number of days on which 1 inch of rain or more fell was forty-nine at the top and fourteen at Fort William ; at the latter place an inch of rain did not fall on any day in January, April, and June. At the top this amount was exceeded on eight days of November, and seven days both in September and December.

Auroras are reported to have been observed on the following dates :— February 26 ; March 3, 29, 30, 31 ; April 2, 5, 6, 23, 24, 25 ; October 1 ; December 20, 21, 22, 23, 24 ; the number being thus relatively few, the sun spots being near the minimum of the eleven-year period.

St. Elmo's Fire was seen on March 10, 24 ; May 13 ; December 29, 30.

Zodiacal Light, not observed during the year.

Thunder and lightning was reported on April 15 ; August 5 ; December 8, 29. Lightning only, July 24 ; August 1, 2, 4, 13.

Solar Halo, March 30 ; April 27 ; May 27 ; August 1, 3 ; September 10, 11, 26 ; October 4, 20.

Lunar Halo, January 13, 21 ; February 12 ; May 13 ; August 9, 12, 22 ; October 4 ; November 10, 16.

As stated in our last Report, the observations at the intermediate station on Ben Nevis, at a height of 2,322 feet, were resumed in the summer months. The observations were made from July 19 to September 30, by Messrs. T. S. Muir of the Royal Hill School of Edinburgh, Alexander Drysdale, B.Sc., Dollar, and A. Aitken. By the great enthusiasm and self-denial of the observers, aided by several self-recording instruments gifted by Mr. J. Y. Buchanan, an invaluable complete series of hourly observations have been obtained. Hence, for the first time, complete series of hourly observations have been secured at heights of 42 feet, 2,322 feet, and 4,407 feet, the three places being in the same line and differing but little in horizontal distance from each other. These hourly observations from the three Observatories on Ben Nevis are really indispensable data in investigating the problems relating to the vertical gradients of the temperature, pressure, and humidity of the atmosphere and its movements.

Messrs. Muir and Drysdale have undertaken, under the superintendence of the Directors, the laborious work of discussing these observations, and at the Meeting of the Scottish Meteorological Society, Mr. Muir submitted an elaborate preliminary report. Among the important results either disclosed or indicated in the discussion may be noticed the relations which obtain between different vertical distributions of temperature and pressure on the one hand, and cyclones and anticyclones on the other, thus :—When the reduced barometer at the Ben Nevis Observatory, for a series of observations, comes out higher than that of Fort William, the accompanying disturbance of temperature takes place in the lower half of the mountain, that is, below the intermediate station, and denotes the approach of an anticyclone. Conversely, when the reduced Ben Nevis Observatory barometer reads lower than that of Fort William, then the disturbance of temperature takes place in the upper half of the mountain, and denotes the approach of a cyclone.

In the further prosecution of this line of research, it has been arranged that in the summer of 1898, in addition to the hourly observations, the observers make temperature and humidity observations at different heights above and below the level of the intermediate station. The observer takes with him dry and wet bulb thermometers (Assmann's) with which the temperature and humidity are observed. Special attention is given to the particular height where at the time the more rapid changes of temperature and humidity occur, which are so striking features on the slopes of Ben Nevis, of the cyclones and anticyclones as they sweep past the mountain. These observations will continue to be made for some time at short intervals, to which are added eye observations, such as mist and haze as they appear or disappear; of marked changes of wind, both direction and force; of the heights of the clouds on the neighbouring heights and mountains, of the rainfall, &c.

Mr. Omond has undertaken a discussion of the hourly observations at the three observatories, carried out in sequence from day to day, with the view of ascertaining, among other points, the times which elapse between the first appearance of the indications of a cyclone or anticyclone, and its actual arrival in the British Islands.

Dr. Buchan has been for some time engaged in the preparation of a paper on the annual rainfall of Scotland, and its variations from year to year in different parts of the country. In carrying out this inquiry, the relation of the whole subject to the sun-spot period of eleven years is under consideration. The last four periods, commencing respectively 1855, 1866, 1877, and 1888, are alone dealt with. The result is that the mean annual variation of the rainfall of Scotland, considered as a whole, from 1855 to 1897, shows a course of variation for the eleven years period closely accordant with the variation of the sun spots. As the sun spots increase from the minimum to the maximum in the sixth year of the period, the rainfall is under the average; but as they fall from the maximum to the minimum during the next five years, the rainfall is above the average.

The averages have been calculated for upwards of 300 stations in Great Britain, and the remarkable result has been arrived at that, for stations in the west, well open to the westerly winds from the Atlantic—and such stations are numerous—the above relation between the distribution of the rainfall and the sun spots during the eleven years periods obtains without exception in the strongest marked form.

An examination of the annual direction and force of the wind for the eleven years period has been made, and sorting the results into two groups, comprising respectively N.W., N., N.E., and E. winds, which may be regarded as dry winds, and S.E., S., S.W., and W. winds as wet or rain-bringing winds, the following is the striking result: the maximum occurrence of the dry winds is coincident with the years when sun spots are increasing to the maximum and the rainfall is under the average; and the maximum occurrence of the wet winds is coincident with the years when sun spots are diminishing towards the minimum and the rainfall is above the average.

Further, the minimum force of the wind is during the former half of the eleven years period when the sun spots are increasing, and the maximum when they are falling to the minimum.

In your Committee's last report it was intimated that there is in course of construction a map for each day of each of the years over which the Ben Nevis Observations extend, on which is entered the amount of the day's rainfall at 120 places in Scotland; the storms of wind from the night and day observations at the Scottish Lighthouses; hours of sunshine; fog, in hours' duration; thunderstorms; halos, auroras, and other phenomena. These are collated with the bi-daily weather maps of the Meteorological Council, and also with the hourly observations of the Ben Nevis Observatories. These have been designed mainly to see what light would thereby be cast on the dynamic effects produced by the condensation and precipitation of the aqueous vapour of the atmosphere.

Now, among other matters, these maps reveal the existence of two very different types of westerly winds. One type has the wind unusually strong and steady, nearly in the same direction at the top of Ben Nevis as at sea level, with the hygrometer showing a great humidity at both observatories, and continuing long and steadily humid. Under these conditions the accompanying rains are more than ordinarily heavy, and virtually overspread all Scotland. The other type is accompanied by a wind at the top of the mountain, nearly in a direction the opposite to what obtains at sea-level at the time, with the hygrometer at one or both observatories indicating great fluctuation in the amount of vapour. Under these conditions the rains deposited do not penetrate far eastwards, and even in strictly western situations are neither very heavy nor protracted.

Somewhat analogous to these westerly winds are the accompanying phenomena of easterly winds, with the notable exception that easterly winds bring with them a rainfall that seldom penetrates to any considerable distance inland from the east coast.

Now in the case of districts which are well protected by mountains in the west-south-westerly direction, but well open to the rain-bringing south-easterly winds, it happens that their curves of rainfall for the sun spot period are diametrically opposite to the rainfall curves of strictly western districts. These local climatological considerations have an important bearing on the methods to be employed in collating the spots of the sun with the varying phenomena of meteorology.

The Application of Photography to the Elucidation of Meteorological Phenomena.—Eighth Report of the Committee, consisting of Mr. G. J. SYMONS (*Chairman*), Professor R. MELDOLA, Mr. J. HOPKINSON, Mr. H. N. DICKSON, *and* Mr. A. W. CLAYDEN (*Secretary*). (*Drawn up by the Secretary.*)

THE work has been continued throughout the year whenever possible, and the number of separate observations made in the course of the last three years amounts to more than 200, about 150 of which were observations of high-level clouds.

It has been found that the low-level cumulus clouds very frequently fail to give any results, as the parallax due to the base line often gives two such very different pictures that no corresponding points of the cloud can be identified. For such clouds a base line of 100 yards would be ample. With the present base line of 200 yards it is not possible to be sure of getting a reliable measurement unless the cloud is at a height of at least 2,000 feet.

Some slight difficulty has been experienced in so drawing the vertical and horizontal lines as to intersect exactly in the centre of the disc given by the image of the sun. This has been especially the case with negatives which give a very dense image of the sun with a considerable amount of deposit around it. But a local reduction of the image has obviated most of the difficulty. This is effected by applying a weak reducer, in the form of a dilute mixture of hyposulphite of soda and ferricyanide of potassium. The plate is wetted, and when the gelatine is thoroughly moistened the reducer is applied with a paint brush to the parts which are too dense. The image of the sun may thus be brought down to any convenient density without risk of diminishing the value of the plate. It is not easy to effect the reduction without showing some streaks and irregular markings, but for the purpose in view these are of no importance.

Few measurements have so far been possible in the winter months, not a single opportunity having presented itself during December, January, or February, and very few during November or March. The determinations made are, therefore, difficult to compare with those which have been made elsewhere, and of which only the mean value has been published, and it is possible that the greater average altitudes observed may be partly explained by the absence of observations during these winter months.

Great altitudes seem especially frequent in hot weather under thunderstorm conditions, in which case the clouds may frequently form at five or six different levels, reaching in some cases to such a height as 80,000 or 90,000 feet, which is three times as great as the mean given for the same type of cloud by the International Meteorological Committee in 1894.

Under similar circumstances around the margins of large thunder depressions clouds of the alto-cumulus and cirro-cumulus types also reach altitudes much greater than the usually accepted means.

At the same time instances are not wanting in which clouds which cannot be distinguished from those types by their appearance occupy much lower levels.

Observations made in different months and at different times of day show a well marked rise of the various cloud planes in hotter weather, and an equally well marked rise during the morning and early afternoon. Both phenomena are, as we should expect, considerably varied by the changes in atmospheric pressure, the greatest altitudes having been recorded at the beginning of a barometric fall after a prolonged spell of anticyclonic conditions, while the lowest altitudes seem to accompany or follow a series of cyclonic disturbances.

There seems reason for suspecting that the high-level clouds reach greater altitudes over the West of England than at other places where observations have been taken, but the variations in the level of a particular type of cloud are so great from week to week, and sometimes even within a single day, that a very prolonged series of determinations ought to be secured before a comparison is made with the researches which have been carried on elsewhere.

The installation remains in an efficient state, little trouble having been experienced with the electrical arrangements, in spite of the long drought and consequent poor 'earth.'

The Secretary proposes to continue the work, and if possible to move the whole installation, which is now arranged with an east and west base line, to some neighbouring site with the line north and south, whereby observations in the early morning and late afternoon will be greatly facilitated. As he is willing to continue to bear the expense no grant is sought, but the Committee ask to be reappointed.

The Action of Light upon Dyed Colours.—Report of the Committee, consisting of Dr. T. E. THORPE (*Chairman*), Professor J. J. HUMMEL (*Secretary*), Dr. W. H. PERKIN, Professor W. J. RUSSELL, Captain ABNEY, Professor W. STROUD, *and* Professor R. MELDOLA. (*Drawn up by the Secretary.*)

THE Report of the Committee presented this year refers to the results obtained during the year 1896–97, in which period a large number of wool and silk patterns, dyed with various natural and artificial *brown* and *black* colouring matters, were exposed to light.

It is with regret that the Committee have to announce the death of James A. Hirst, Esq., in whose grounds at Adel, near Leeds, all the patterns experimented upon since 1892 have been exposed. Mr. Hirst took great interest in the work of this Committee, and the same interest is shown by his son, E. A. Hirst, Esq., who has expressed the pleasure it gives him in being able to aid in the continuation of the work.

The general method of preparing the dyed patterns and the manner of exposing them under glass, with free access of air and moisture, were the same as already adopted in previous years.

Each dyed pattern was divided into six pieces, one of which was protected from the action of light, while the others were exposed for different periods of time. These 'periods of exposure' were made equivalent to those adopted in previous years by exposing, along with the patterns, special series of 'standards,' dyed with the same colouring matters as were then selected for this purpose. The standards were allowed to fade to the same extent as those which marked off the 'fading period' in previous years, before being renewed, or before removing a set of dyed patterns from the action of light. The patterns exposed during 1896–97 are, therefore, comparable, in respect of the amount of fading action to which they have been submitted, with the dyes already reported upon.

The patterns were all put out for exposure on July 22, 1896, certain sets being subsequently removed on the following dates:—August 22, September 29, November 5, 1896; May 22, September 6, 1897. Of these five 'periods of exposure' thus marked off, periods 1, 2, 3 were equivalent to each other in fading power, whereas periods 4 and 5 were each equivalent to *four* of the first period in this respect; hence five patterns of each colour have been submitted respectively to an amount of fading equal to 1, 2, 3, 7, and 11 times that of the first 'fading period' selected—viz. July 22 to August 22, 1896.

The dyed and faded patterns have been entered in pattern-card books in such a manner that they can be readily compared with each other.

The following tables give the general result of the exposure experiments made during 1896–97, the colours being divided, according to their behaviour towards light, into the following five classes: Very fugitive, fugitive, moderately fast, fast, very fast.

The initial numbers refer to the order of the patterns in the pattern-books. The S. and J. numbers refer to Schultz and Julius's 'Tabellarische Uebersicht der künstlichen organischen Farbstoffen.'

In the case of colouring matters requiring mordants, the particular mordant employed is indicated in brackets after the name of the dyestuff.

The colours marked thus (*) appear to be somewhat faster than the rest of the class in which they are placed.

BROWN COLOURING MATTERS.

Class I. Very Fugitive Colours. (Wool.)

The colours of this class have faded so rapidly that at the end of the first 'fading period' (July 22 to Aug. 22, 1896) only a very faint colour remains, or it has become very materially altered in hue. At the end of the fifth period (about one year) all traces of the original colour have disappeared, the woollen cloth exhibiting merely a yellowish, brownish, or greyish tint, according to the colour of the original pattern.

Azo Colours.

Wool Book XII.		
Basic Colours.	1.	Leather Brown R. Constitution not published.
,,	2.	Chrysoïdine AG. From aniline and *m*-phenylene-diamine. S. and J. III. 16.
,,	3.	Chrysoïdine FF. From aniline and *m*-toluylene-diamine.
,,	8.	Leather Brown V. Constitution not published.
Direct Cotton Colours.	1.	Titan Brown Y. Constitution not published.
	2.	Benzo Brown 5R. From Primuline and phenylene-diamine. S. and J. III. 110.
,,	*4.	Cloth Brown (red shade). From benzidine, salicylic acid, and α-naphthol-sulphonic acid NW. S. and J. III. 193.
,,	13.	Benzo Brown G. From sulphanilic acid and Bismarck Brown. S. and J. III. 273.
,,	25.	Hessian Brown MM. From sulphanilic acid, tolidine, and resorcinol. S. and J. III. 278.

Azoxy Colours.

Wool Book XII.		
Direct Cotton Colours.	21.	Mikado Brown M. Constitution not published.

Notes.—In the case of Chrysoïdine AG and FF, and Cloth Brown, the colours alter very rapidly during the first 'period of exposure,' the altered colours then fade more slowly, without any further change in hue.

Class II. Fugitive Colours. (Wool.)

The colours of this class show very marked fading at the end of the second 'fading period' (August 22 to September 29, 1896), and after a year's exposure they have entirely faded, or only a brownish, drab, or grey tint remains.

Azo Colours.

Wool Book XII.		
Acid Colours.	1.	Resorcin Brown. From *m*-xylidine, sulphanilic acid, and resorcinol. S. and J. III. 163.
,,	2.	Fast Brown G. From sulphanilic acid and α-naphthol. S. and J. III. 165.
,	4.	Acid Brown G. From aniline and *m*-diamido-azo-benzene-*p*-monoulphonic acid. S. and J. II. 136.

Wool Book XII.

Acid Colours. 7. Naphthylamine Brown. From naphthionic, acid and α-naphthol. S. and J. III. 92.
„ 8. Sulphamine Brown. From α-naphthylamine and nitroso-β-naphthol-sodium-bisulphite. S. and J. III. 57.
„ 9. Acid Brown R. From naphthionic acid and Chrysoïdine. S. and J. II. 91.
„ 10. Alkali Brown. From Primuline and *m*-phenylene-diamine. S. and J. III. 110.
„ 11. Fast Brown 3B. From β-naphthylamine-sulphonic acid Br and α-naphthol. S. and J. III. 103.

Wool Book XIII.

Basic Colours. *1. Chrome Brown RO (Cr). From naphthionic acid and α-naphthol. S. and J. III. 92.
„ *2. Chrome Brown BO (Cr). Constitution not published.
„ *3. Chrome Brown R (Cr). Constitution not published.
„ 4. Nut Brown. From *m*-toluylene-diamine and *m*-toluylene-diamine. S. and J. III. 174.
„ *5. Bismarck Brown 2G. From *m*-phenylene-diamine and *m*-phenylene-diamine. S. and J. III. 172.
„ *6. Leather Brown. From amido-*p*-acetanilide and *m*-phenylene-diamine; products treated with HCl. S. and J. III. 160.
„ *7. Leather Brown O. Similar to Leather Brown.
Direct Cotton Colours. 8. Diazochromine BS. Constitution not published.
11. Toluylene Brown R. From sulphanilic acid and Bismarck Brown sulphonic acid.
„ 15. Direct Brown Y. From *m*-amido-benzoïc acid and Bismarck Brown. S. and J. III. 275.
„ 19. Cloth Brown (yellow shade). From benzidine and salicylic acid and dioxy-naphthalene (2·7). S. and J. III. 194.
„ 26. Catechu Brown. From Bismarck Brown and *m*-phenylene diamine. S. and J. II. 220.
„ 27. Congo Brown VBB. Constitution not published.
„ *28. Catechu Brown DDX. Constitution not published.
„ *29. Catechu Brown DDDX. Constitution not published.
„ *30. Hessian Brown B. Constitution not published.
„ *31. Azo Brown. Constitution not published.
„ *32. Toluylene Brown R. Constitution not published.
„ *33. Benzo Brown. Constitution not published.
„ *34. Benzo Brown BR. Constitution not published.
„ *35. Benzo Brown B. From naphthionic acid and Bismarck Brown. S. and J. III. 274.
„ *36. Benzo Brown NB. Constitution not published.
„ *37. Toluylene Brown M. Constitution not published.
„ *38. Toluylene Brown B. Constitution not published.
„ *39. Cotton Brown A Constitution not published.
„ *40. Cotton Brown N. Constitution not published.
„ 42. Toluylene Brown VO. Constitution not published.
„ 44. Toluylene Brown 2BO. Constitution not published.
„ 46. Benzo Black Brown. Constitution not published.
„ 47. Sulphon Brown R. Constitution not published.
„ *48. Sulphon Dark Brown. Constitution not published.
Direct Cotton Colours developed. 2. Diazo Brown R (extra). Constitution not published. Azotised and developed with β-naphthol.
*3. Zambesi Brown G. Constitution not published. Azotised and developed with toluylene-diamine.
„ 4. Diazo Brown G. Constitution not published. Azotised and developed with β-naphthol.
„ 5. Zambesi Brown 2G. Constitution not published. Azotised and developed with toluylene-diamine.
„ 6. Diazo Brown Y. Constitution not published. Azotised and developed with β-naphthol.
„ 7. Diazo Brown V. Constitution not published. Azotised and developed with β-naphthol.

Wool Book XIII.

Direct Cotton Colours developed.	*8.	Diamine Brown V. From benzidine and amido-naphthol-sulphonic acid and *m*-phenylene diamine. S. and J. III. 182. Azotised and developed with phenylene-diamine.

Natural Colouring Matters.

Mordant Colours.	6.	Sanderswood (Cr). Pterocarpus santalinus (wood).
	7.	Barwood (Cr). Baphia nitida (wood).
,,	*8.	Ventilago (Cr). Ventilago madraspatana (root-bark).
,,	10.	Camwood (Cr).
,,	11.	Limawood (Cr) (Cu). Cæsalpinia echinata (wood).
,,	*13.	Catechu (Cr). Areca catechu (extract).

NOTES.—Leather Brown and Leather Brown O might almost equally well be classed as 'moderately fast' colours. In the first 'fading period' they become somewhat greyish in hue, but the altered colour fades very gradually, leaving at the end of a year a fairly good drab-grey colour.

CLASS III. MODERATELY FAST COLOURS. (WOOL.)

The colours of this class show distinct fading at the end of the second period (August 22 to September 29, 1896), which becomes more pronounced at the end of the third period (September 29 to November 5, 1896). A pale tint remains at the end of the fourth 'period of exposure' (November 5, 1896, to May 22, 1897), and at the end of a year's exposure the colour has entirely faded, or at most only traces of colour remain.

Azo Colours.

Wool Book XII.

Acid Colours.	*3.	Azo Acid Brown. Constitution not published.
,,	6.	Fast Brown. From xylidine-mono-sulphonic acid, and α-naphthol. S. and J. II. 80.
,,	12.	Fast Brown. From naphthionic acid, and resorcinol. S. and J. III. 164.
,,	14.	Diamond Brown. Constitution not published.
Direct Cotton Colours.	7.	Congo Brown G. From sulphanilic acid and benzidine, with resorcinol and salicylic acid. S. and J. III. 269.
,,	9.	Thiazine Brown G. Constitution not published.
,,	12.	Congo Brown R. From α-naphthylamine-sulphonic acid L and benzidine, with resorcinol and salicylic acid. S. and J. III. 270.
,,	14.	Hessian Brown 2BN. Constitution not published.
,,	16.	Hessian Brown 2B. From sulphanilic acid and benzidine, with resorcinol. S. and J. III. 277.
,,	17.	Thiazine Brown R. Constitution not published.
,,	20.	Diamine Bronze G. From benzidine, with salicylic acid and amido-naphthol-disulphonic-acid-H-azo-*m*-phenylene-diamine. S. and J. III. 263.
,,	41.	Diamine Brown M. From benzidine, with salicylic acid and γ-amido-naphthol-sulphonic acid.
,,	43.	Diamine Brown B. From benzidine, with phenyl-γ-amido-naphthol-sulphonic acid.
,,	45.	Benzo Dark Brown. Constitution not published.
Direct Cotton Colours developed.	*1.	Diamine Cutch. Constitution not published. Naphthylene Violet azotised and developed with sodium carbonate. S. and J. III. 256.

Azoxy Colours.

Direct Cotton Colours.	22.	Mikado Brown 2B. Constitution not published.
	23.	Mikado Brown G. Constitution not published.
,,	24.	Mikado Brown B. Constitution not published.

Natural Colouring Matters.

Wool Book XIII.
Mordant Colours *Ventilago (Cu) (Fe). Ventilago madraspatana (root-bark).
„ Sanderswood (Cu) (Fe). Pterocarpus santalinus (wood).
„ Barwood (Cu) (Fe). Baphia nitida (wood).
„ Camwood (Cu) (Fe).

Notes.—Diamine Brown M loses its reddish hue and becomes apparently darker during the first 'fading period'; the altered colour fades slowly, and finally leaves at the end of a year a pale drab colour. Azo Acid Brown acquires a more yellowish hue during the first 'fading period'; the colour then fades very gradually without further change of hue, leaving at the end of a year a very pale brown. It might fairly well be classed as a 'fast colour.' The Mikado Browns are by no means so fast to light as the Mikado Oranges and Yellows: they experience the greatest change in depth of colour during the first 'fading period'; the altered colour, which is yellower than the original one, then fades very gradually, and leaves at the end of a year a fairly good buff colour.

Class IV. Fast Colours. (Wool.)

The colours of this class show comparatively little fading during the first, second, and third periods. At the end of the fourth 'period of exposure' a pale shade remains, which at the end of the year's exposure still leaves a pale shade.

Azo Colours.

Wool Book XII.
Direct Cotton Colours. 5. Toluylene Brown G. From toluylene-diamine-sulphonic acid and m-phenylene-diamine. S. and J. III. 241.
„ 6. Direct Cotton Brown R. From amido-nitroso-stilbene-disulphonic acid and aniline.

Natural Colouring Matters.

Wool Book XIII.
Mordant Colours. 12. Cochineal (Cr). Coccus cacti (insect).

Class V. Very Fast Colours. (Wool.)

The colours of this class show a very gradual fading during the different periods, and even after a year's exposure a moderately good colour remains.

Oxyketone Colours.

Wool Book XIII.
Mordant Colours. Alizarin Bordeaux B (Cr) (Cu). Tetra-oxy-anthraquinone (1.2.5.8). Quinalizarin. S. and J. III. 403.
„ Alizarin Bordeaux G (Cr) (Cu).
„ Alizarin Bordeaux GG (Cr) (Cu).
„ Alizarin Maroon (Cr) (Cu). Amido-purpurin. S. and J. III. 394.
„ Alizarin Brown (Cr) (Fe). Diamido-alizarin.
„ Anthracene Brown (Cr) (Fe). Tri-oxy-anthraquinone (1.2.3) Anthragallol. S. and J. III. 396.

Natural Colouring Matters.

Wool Book XIII.
Mordant Colours. Morinda Root (Cr) (Cu) (Fe). Morinda citrifolia (root).
„ Mang-kudu (Cr) (Cu) (Fe). Morinda umbellata (root-bark).
„ Chay Root (Cr) (Cu) (Fe). Oldenlandia umbellata (root).
„ Munjeet (Cr) (Cu) (Fe). Rubia cordifolia (root).
„ Madder (Cr) (Cu) (Fe). Rubia tinctorum (root).
„ Lac-dye (Cr) (Cu) (Fe). Coccus ilicis (insect).
„ Cochineal (Cu) (Fe). Coccus cacti (insect).

Additional Colours.

Oxidation Colour. Chromogen I. (1 . 8) Dioxy-naphthalene- (3 . 6) disulphonic acid; oxidised with bichromate of potash. S. and J. III. 504.

BLACK COLOURING MATTERS.

Class I. Very Fugitive Colours. (Wool.)

Azo Colours.

Wool Book XIV.
Acid Colour. 4. Violet Black. From *p*-phenylene-diamine, with α-naphthylamine and α-naphthol-sulphonic acid NW. S. and J. III. 502.
Direct Cotton Colours 1. Nyanza Black B. From *p*-phenylene-diamine-azo-α-naphthylamine and amido-naphthol-sulphonic acid γ.
„ 2. Tabora Black R. Constitution not published.

Notes.—During the first 'fading period' Violet Black changes to a dull vinous red colour.

Class II. Fugitive Colours. (Wool.)

Azo Colours.

Wool Book XIV.
Acid Colours. 6. Azo Nigrine R. From phenol-disulphonic-acid-azo-α-naphthylamine and β-naphthol.
„ 12. Wool Black. From amido-azo-benzene-disulphonic acid and *p*-tolyl-β-naphthylamine. S. and J. III. 139.
„ 13. Jet Black G. Constitution not published.
„ 19. Phenylene Black. From α-naphthylamine-disulphonic acid-azo-α-naphthylamine and diphenyl-*m*-phenylene-diamine. S. and J. III. 152.
„ 21. Anthracite Black R. From α-naphthylamine-disulphonic acid and α-naphthylamine-azo-diphenyl-*m*-phenylene diamine.
„ 26. Azo Acid Black B. Constitution not published.
„ 27. Azo Acid Black G. Constitution not published.
Direct Cotton Colours 10. Direct Deep Black T. Constitution not published.
11. Columbia Black 2B. Constitution not published.
„ 12. Columbia Black B. Constitution not published.
„ 13. Oxy Diamine Black N. Constitution not published.
„ 14. Union Black S. Constitution not published.
„ 16. Oxy Diamine Black SOOO. Constitution not published.
„ 18. Columbia Black R. Constitution not published.
Direct Cotton Colours developed. 1. Diamine Black BH. From benzidine, and γ-amido-naphthol-sulphonic acid, and amido-naphthol-disulphonic acid H; developed with Fast Blue Developer AD.
„ 2. Diazo Black B. From benzidine and α-naphthylamine-sulphonic acid L; developed with β-naphthol.

Wool Book XIV.

Direct Cotton Colours developed	*3.	Diamine Black ROO. From benzidine and β-amido-naphthol-sulphonic acid; developed with Fast Blue Developer AD. S. and J. III. 187.
„	4.	Diazo Black R. Constitution not published. Developed with β-naphthol.
„	5.	Diazo Black H. Constitution not published. Developed with β-naphthol.
„	*8.	Diamine Black BO. From ethoxy-benzidine and amido-naphthol-sulphonic acid γ; developed with Fast Blue Developer AD. S. and J. III. 229.

Oxazine Colours.

Basic Colours. 1. Cotton Black. Constitution not published.

Natural Colouring Matters.

Mordant Colours. Limawood (Fe). Cæsalpinia echinata (wood).

Notes.—The following colours acquire a reddish or purplish tint during the fading process: Azo Acid Blacks B and G, Columbia Blacks B and R, Union Black S, Oxy-diamine Black SOOO, Diamine Black RO and BO. An olive tint is acquired by Direct Deep Black T.

Class III. Moderately Fast Colours. (Wool.)

Induline Colours.

Wool Book XIV.

Acid Colours.	*9.	Nigrisine. Sodium salt of an induline-sulphonic acid. S. and J. III. 475.
„	*10.	Brilliant Black EB. Constitution not published.
Basic Colours	2*a*.	Nigrisine J. Condensation product of *p*-nitroso-dimethyl-aniline
„	3*a*.	Nigrisine. Similar to Nigrisine J. S. and J. III. 502.

Azo Colours.

Acid Colours	*5.	Naphthol Black 4R. Constitution not published
„	8.	Jet Black R. From amido-benzene-disulphonic-acid-azo-α-naphthylamine and phenyl-α-naphthylamine. S. and J. III. 150.
„	11.	Naphthylamine Black. From α-naphthylamine-disulphonic-acid-azo-α-naphthylamine and α-naphthylamine. S. and J. III. 153.
„	*41.	Acid Black B. Constitution not published.
„	16.	Acid Black 2B. Constitution not published.
„	*17.	Naphthol Black 6B. From α-naphthylamine-disulphonic acid-azo-α-naphthylamine and β-naphthol-disulphonic acid R. S. and J. III. 154.
„	*18.	Naphthol Black 3B. Constitution not published.
„	*20.	Victoria Black B. From sulphanilic acid-azo-α-naphthylamine and β-naphthol-sulphonic acid S. S. and J. III. 149.
„	*22.	Naphthol Black B. From β-naphthylamine-γ-disulphonic acid-azo-α-naphthylamine and β-naphthol-disulphonic acid R. S. and J. III. 157.
„	25.	New Victoria Black Blue. Constitution not published.
„	28.	Naphthylamine Black 6B. Constitution not published.
„	*29.	Victoria Black Blue. Constitution not published,
„	30.	Naphthylamine Black 4B. Constitution not published.
„	31.	New Victoria Black B. Constitution not published.
„	*32.	Victoria Black G. Constitution not published.
„	*33.	Victoria Black 5G. Constitution not published.
„	34.	New Victoria Black 5G. Constitution not published.

Wool Book XIV.

Basic Colours.	*3.	Diazine Black. From Safranine and phenol.
Direct Cotton Colours.	3.	Benzo Black Blue G. From benzidine-disulphonic acid, with α-naphthylamine-azo-α-naphthol-sulphonic acid NW and α-naphthol-sulphonic acid NW. S. and J. III. 266.
,,	4.	Benzo Black Blue R. From tolidine, with α-naphthylamine-azo-α-naphthol-sulphonic acid NW and α-naphthol-sulphonic-acid NW. S. and J. III. 266.
,,	5.	Benzo Black. Constitution not published.
,,	6.	Benzo Black S extra. Constitution not published.
,,	7.	Diamond Jet Black OO. Constitution not published.
,,	8.	Chicago Grey. Constitution not published.
,,	9.	Diamine Jet Black SS. Constitution not published.
,,	15.	Diamine Black HW. Constitution not published.
,,	17.	Benzo Black Blue 5G. From benzidine-disulphonic acid, with α-naphthylamine-azo-dioxynaphthalene-sulphonic acid S and dioxynaphthalene-sulphonic acid S. S. and J. III. 267.
Direct Cotton Colours developed	6.	Diazo Brilliant Black B. From tolidine and α-naphthylamine-sulphonic acid L; developed with β-naphthol.
	7.	Diazo Brilliant Black R. Constitution not published. Developed with β-naphthol.
Mordant Colour	1.	Chrome Black (Cr). Constitution not published.
,,	3.	Diamond Black (Cr). From amido-salicylic-acid-azo-α-naphthylamine and α-naphthol-sulphonic acid NW. S. and J. III. 159.
,,	4.	Diamond Black NG (Cr). Constitution not published.
,,	5.	Diamond Black GA (Cr). Constitution not published.

Natural Colouring Matters.

Mordant Colours.	Logwood (Cr) (Fe*). Hæmatoxylon campechianum (wood).
	Cochineal (Fe*). Coccus cacti (insect).

Notes.—The colours dyed with the two Nigrisines are medium shades of grey: they do not alter materially in hue during the fading process, and at the end of the third period of exposure they still appear as pale greys. The following colours alter very little in hue while fading, and fade so gradually that they might fairly well be thought worthy of being classed as 'Fast Colours:' Nigrisine, Brilliant Black EB, Acid Black B, Naphthol Blacks 3B and 6B, Victoria Blacks B, G, and 5G, Victoria Black Blue. Diazine Black acquires a somewhat yellowish cast at the end of the first period of exposure, and then fades so slowly that even at the end of a year a full grey shade remains.

Several of the artificial black colours in this class are quite as fast to light as the black obtained with logwood on chromium mordant; some indeed seem to be more permanent, and they do not acquire the characteristic olive tint of the faded logwood and chromium black. With iron mordant logwood gives a somewhat faster black than that obtained with chromium; the same appears to be the case with Chrome Black and the various marks of Diamond Black.

CLASS IV. FAST COLOURS. (WOOL.)

Azo Colours.

Wool Book XIV.

Mordant Colours.	5.	Chrome Black (Fe). Constitution not published.
,,	6.	Diamond Black (Fe). From amido-salicylic acid-azo-α naphthylamine and α-naphthol-sulphonic acid NW. S. and J. III. 159.
,,	7.	Diamond Black NG (Fe). Constitution not published
,,	8.	Diamond Black GA (Fe). Constitution not published.

Oxyketone Colours.

Mordant Colours	* Alizarin Black SW (Cr) (Fe). Sodium bisulphite compound of dioxy-naphthoquinone. S. and J. III. 385.
"	* Alizarin Bordeaux G (Fe). Constitution not published.
"	* Alizarin Bordeaux B (Fe). Tetra-oxy-anthraquinone (1 . 2 . 5 . 8). Quinalizarin. S. & J. III. 403.

CLASS V. VERY FAST COLOURS. (WOOL.)

Oxyketone Colours.

Wool Book XIV.	
Mordant Colours	Alizarin Bordeaux GG (Fe). Constitution not published.

Silk Patterns.

Most of the foregoing colours were also dyed on silk, and the patterns were exposed to light along with the woollen patterns. The relative fastness of the various colours is generally the same as on wool, and a special classification for silk seems unnecessary.

The Carbohydrates of the Cereal Straws.—Third Report of the Committee, consisting of Professor R. WARINGTON *(Chairman)*, Mr. MANNING PRENTICE, *and* Mr. C. F. CROSS *(Secretary)*. *(Drawn up by* Mr. CROSS.)

THE work, which was carried out in the agricultural season of 1897, has been reported upon in a paper published in the 'Journal of the Chem. Soc.' 1898, p. 459. The purpose of these later investigations was to trace the effect of removing the seed-bearing organs upon the carbohydrates of the stem. The results were, however, negative, adding another confirmation to the conclusion previously arrived at, that the carbohydrates of the stem tissues are built up with a constant ratio of 'furfural-yielding' to normal hexose carbohydrates. Further evidence was also obtained that these two groups of carbohydrates are in the earlier stages of growth similarly attacked by boiling dilute acids, and after such hydrolysis are similarly fermented by yeast.

It must in fact be admitted that as condensation to furfural is by no means an exclusive characteristic of C_5 Carbohydrates, there is no evidence whatever that the furfuroids of the barley straw are, in the early stages of growth, pentose-anhydrides or pentosanes.

There now appears in the 'Journ. Fed. Inst.' Brewing, 1898, p. 438, an article by Tollens under the title 'On the Carbohydrates of Barley and Malt, with special reference to the Pentosanes,' in which, as a result of yeast fermentations of the products of acid hydrolysis of brewers' grains, the author arrives at the following conclusions :—'From the behaviour of these furfural-yielding substances on fermentation we are forced to the view that they behave, to some extent, similarly to the ordinary hexoses, and somewhat different from the pentoses, for when brought into contact with yeast they exhibit certain manifestations of fermentation ; but they give rise to the formation of but little alcohol and much acid. It must be concluded from this that the furfural-yielding substances . . . contain a certain amount of other substances more susceptible to fermentation than arabinose and xylose. They may contain glycuronic acid or oxycelluloses. . . .'

We are very glad to have this confirmation from so great an authority as Professor Tollens, and we will not quarrel with his decision 'to retain the old name pentosanes for this group of substances,' instead of 'the indefinite name of furfuroids proposed by Cross and Bevan.' We will only remark that, as the idea has been abandoned that they are exclusively and definitely pentosanes, it appears more logical to adopt a term of corresponding significance.

We ourselves have recently carried out a more extended series of fermentation experiments which further define these products, and the results of this work will be published in the course of the autumn.

Generally, the position for which we have long contended may be taken as fully established, viz. that the plant world affords a group of furfural-yielding bodies, probably carbohydrates, which are susceptible of fermentation by yeast.

We have next resumed the study of the problem of the relationship of such compounds to the normal hexoses, on the basis of the purely chemical probabilities. We have previously shown that furfuroids are produced from the hexoses by many processes of oxidation. One such process, which we had overlooked, appeared from the researches of Fenton in the province of the dicarboxylic acids to be capable of extension to other hydroxy compounds, such as the carbohydrates—that is, the action of hydrogen peroxide in presence of iron salts. A research in this direction has led to positive results. We have not only succeeded in producing furfuroids in some quantity—7 to 9 per cent. of the hexaldoses—but we find that dicarbonyl derivatives are produced reacting with phenylhydrazine acetate in the cold to form dihydrazones, which appear to be osazones. We have published a preliminary account of this research in the 'Journal of the Chem. Soc.' 1898, p. 463, and since the publication of the paper we have been joined in the investigations by Dr. R. S. Morrell. Results have been obtained confirming and extending those of our preliminary paper, and these will be published in the course of the autumn. We have every expectation that the investigations will lead to results of physiological significance by elucidating processes actually taking place in the plant-cell.

The Electrolytic Methods of Quantitative Analysis.—Fifth Report of the Committee, consisting of Professor J. EMERSON REYNOLDS (*Chairman*), Dr. C. A. KOHN (*Secretary*), Professor P. FRANKLAND, Professor F. CLOWES, Dr. HUGH MARSHALL, Mr. A. E. FLETCHER, *and* Professor W. CARLETON WILLIAMS.

A CONSIDERABLE portion of the experimental work in progress last year has now been completed, and the investigations on the determination of zinc, cobalt and nickel are included in the present Report. Further work on the determination of bismuth, the first portion of which was published in the third report of the Committee, is in hand, but is not yet ready for publication. It is proposed to proceed with the study of the methods for separating cobalt, nickel, iron and zinc respectively from other metals. The Committee ask for reappointment, without further grant.

The Determination of Zinc. *By* Professor W. CARLETON WILLIAMS, *B.Sc.*

Bibliography.

Author	Journal	Year	Vol.	Page	Composition of Electrolyte
Wrightson, F.	Zeits. anal. Chem.	1876	15	297	Ammonium hydrate
Millot, A.	Bull. Soc. Chim.	1877	32	482	Potassium cyanide
Riché, A.	Compt. Rend. .	1877	85	226	Ammonium sulphate, hydrate, and acetic acid
Parodi, G., & Mascazzini, A.	Zeits. anal. Chem.	1877	16	469	Ammonium acetate
" " " "	Ber. . . .	1877	10	1098	Ammonium acetate and citric acid
" " " "	Zeits. anal. Chem.	1879	18	587	
Beilstein, A., and Jawein, J.	Ber. . . .	1879	12	446	Potassium cyanide
Luckow, C. . . .	Zeits. anal. Chem.	1880	19	1	Alkali acetate, tartrate or citrate Ammonium hydrate Potassium cyanide
Classen, A., and Reis, M. A.	Ber. . . .	1881	14	1622	Ammonium oxalate
Reinhardt and Ihle . .	J. prakt. Chem. .	1881	24	193	Potassium oxalate
Millot, A.	Bull. Soc. Chim. .	1882	37	339	Alkali hydrate
Riché, A.	Ann. Chim. et Phys.	1882	13	508	Ammonium sulphate and sulphuric acid
Luckow, C. . . .	Chem. Zeit. .	1885	9	338	Hydrochloric acid; *as amalgam* Sulphuric acid; *as amalgam*
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Classen, A.	Ber. . . . Zeits. Electro-Chem.	1894 1894	27 1	2060 280	Ammonium or potassium oxalate and tartaric acid
Thomälen, H. . . .	Zeits. Electro-Chem.	1894	1	304	Sodium acetate and acetic acid Potassium oxalate and sulphate
Jordis, E.	Zeits. Electro-Chem.	1895	2	140, 565, 655	Ammonium lactate, glycollate, and sulphate
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Wagner, E.	Zeits. Electro-Chem.	1896	2	614	Ammonium oxalate and tartaric acid
" "	Zeits. Electro-Chem.	1896	3	19	Ammonium oxalate and tartaric acid
Wolman, L.	Zeits. Electro-Chem.	1897	3	539	Comparison of different methods for estimating zinc

The preceding references show that a large number of electrolytic processes for the estimation of zinc have been proposed during the last twenty years, many of which are said to yield accurate results. Seven of these methods have been investigated. Since the completion of these experiments in 1897, a comparison of the different methods for the estimation of zinc has been published by Wolman (v. *ante*). This has made further work on the simple estimation of zinc unnecessary; our comparative conclusions are contrasted in the sequel. The methods examined were based on the deposition of zinc from a solution containing :—

i. Sodium pyrophosphate.
ii. Alkaline oxalate in neutral or alkaline solution.
iii. Alkaline oxalate in presence of potassium sulphate.
iv. Potassium or ammonium oxalate and free tartaric acid.
v. Potassium cyanide.
vi. Potassium cyanide and sodium phosphate.
vii. Ammonium lactate and ammonium sulphate.

In the following experiments the zinc was always present as sulphate, and the metal was deposited in platinum basins, which were protected from the action of the zinc by a deposit of copper, which extended three or four millimetres beyond the surface of the liquid, during the electrolysis. The basins are coppered by means of a hot solution of copper ammonium oxalate containing free oxalic acid, with a current density of 0·5 to 1 ampere ; the operation only requires two or three minutes. Unfortunately, the layer of copper must be renewed for each zinc determination. Experiments were made with the object of protecting the platinum with layers of gold or silver, but, on the whole, better results were obtained with the coppered basins. If the zinc is deposited on the unprotected surface of the platinum a black stain is produced, when the zinc deposit is dissolved in acid. According to Vortmann (*Ber.* **24**, 2753) the black deposit consists of finely divided platinum.

The end of the reaction was generally ascertained by tilting the vessel or increasing the volume of the solution, so that the liquid came in contact with an unaltered layer of copper. In a small number of determinations the end was ascertained by hanging a narrow strip of metallic copper over the side of the basin ; if the colour of the copper remains unchanged, the precipitation of the zinc is complete. As the last traces of zinc are deposited with difficulty the current density is always increased to one ampere at least towards the end of the operation. The deposit was washed with water without interrupting the current. It was finally washed with alcohol and dried at 80°. No signs of oxidation were noticed.

I.—*Deposition of Zinc from Solution of Pyrophosphate.*

Brand's method is simple and accurate. The solution of zinc salt is mixed with 4 grme. of sodium pyrophosphate and with about 5 c.c. of a saturated solution of ammonium carbonate ; water is added until the liquid measures 120 or 150 c.c., and the mixture is electrolysed. The zinc is obtained as a bright bluish-white deposit, adhering firmly to the basin.

Experiment	Zinc taken : grme.	Zinc found : grme.	C.D.$_{100}$ Amperes	Time : hours	E.M.F. Volts	Error in mgrme.
1	0·2342	0·2347	0·2	7	—	+0·5
2	0·0507	0·0502	0·2 – 1·0	7	—	–0·5
3	0·0733	0·0738	0·16 – 0·8	7	—	+0·5
4	0·1551	0·1551	0·45	6	—	0·0
5	0·2174	0·2171	0·53 – 2·	4	7·5	–0·3
6	0·2185	0·2190	0·5 – 1	4	7·7	+0·5

II.—*Deposition of Zinc from Solution of Double Oxalate.*

In 1881 Classen, and also Reinhardt and Ihle, suggested the addition of potassium or ammonium oxalate, or of both oxalates, to the zinc salt. The electrolysis is carried on at the ordinary temperature.

The method yields good results when the quantity of zinc does not exceed 0·2 grme.; when larger quantities of zinc are taken the deposit is liable to be dull and spongy instead of firm and bright.

Experiment	Zinc taken: grme.	Zinc found: grme.	$C.D._{100}$ Amperes	Time: hours	E.M.F. Volts	Error in milligrms.
1	0·1635	0·1638	0·18	3	4·0	+0·3
2	0·2103	0·2098	0·67	4	4·0	−0·5
3	0·3154	0·3148	0·22	4	3·7	−0·6
4	0·1087	0·1091	0·2	5	4·0	+0·4
5	0·0384	0·0382	0·2	4	4·0	−0·2
6	0·0362	0·0359	0·2	4	4·0	−0·3
7	0·2044	0·2043	0·22	4	4·0	−0·1
8	0·2044	0·2041	0·22	4	3·9	−0·3
9	0·0719	0·0717	0·22	4	4·0	−0·2
10	0·1087	0·1084	0·22	4	4·2	−0·3
11	0·0740	0·0740	0·22	4	6·0	0·0
12	0·2861	0·2852	0·22	4	4·0	−0·9, loose, spongy

In experiments 1, 2, 3 and 12 the zinc salt dissolved in water was poured into a hot solution of potassium oxalate (8 grme.); in 4 and 5 ammonium oxalate (8 grme.) was substituted for the potassium salt; and in experiments 6 to 11 a mixture of potassium oxalate (6 grme.) and ammonium oxalate (2 grme.) was used. This mixture gave the best results.

III.—*Deposition of Zinc from Solution of Alkaline Oxalate and Sulphate.*

The addition of potassium sulphate (3 grme.) to the potassium oxalate (4 grme.), as recommended by Miller and Kiliani, does not appear to improve the process.

Experiment	Zinc taken: grme.	Zinc found: grme.	$C.D._{100}$ Ampères	E.M.F. Volts	Error in mgrme.	Remarks
1	0·2044	0·2032	0·4	4	−1·2	Black spots
2	0·1051	0·1047	0·14	4	−0·4	Bright
3	0·0732	0·0733	0·17	6	+0·1	Black spots
4	0·2729	0·2726	0·28	7·8	−0·3	Bright
5	0·0740	0·0734	0·2	4	−0·6	Bright

The zinc is deposited as a bright, firmly-adhering film, occasionally marked by black spots. Classen quotes experiments in the fourth edition of his 'Quantitative Analyse durch Elektrolyse' showing that this method yields low results.

IV.—*Deposition from Hot Solution of Alkali Oxalate in Presence of Tartaric Acid.*

The solution of zinc sulphate is mixed with 4 grme. of potassium or ammonium oxalate, diluted with water, and electrolysed at a temperature of about 60° C. After the current has passed through the mixture for three minutes, the solution is acidified with tartaric acid, and kept acid throughout the operation by the addition of a 6 per cent. solution of tartaric acid.

Wagner recommends that the hot solution should be electrolysed with a current of 0·2 ampere for fifteen minutes; 5 c.c. of 6 per cent. tartaric acid solution are added and the current density increased to 0·5 ampere. The addition of the acid is repeated at intervals of fifteen minutes.

In the following experiments Wagner's directions were followed, with the exception that the tartaric acid was slowly added from a burette instead of in quantities of 5 c.c. A large excess of acid is to be avoided, and its addition should not be continued up to the end of the operation. The current is continued until the mixture has a neutral or feebly acid reaction, in order to prevent a small quantity of the acid tartrate of potassium or ammonium separating out.

Experiment	Zinc taken: grme.	Zinc found: grme.	$C.D._{100}$ Ampères	E.M.F. Volts	Time: hours	t° C.	Error in mgrme.
1	0·2103	0·2098	0·56	4	3	60	−0·5
2	0·0580	0·0582	0·5	8	3	60	+0·2
3	0·0435	0·0436	0·56	6	3	60	+0·1
4	0·2339	0·2344	0·56	8	3	60	+0·5
5	0·0909	0·0929	0·4	6	2½	60	+2
6	0·2446	0·2457	0·5	8	2½	60	+1·1
7	0·1087	0·1092	0·5	6	2½	60	+0·5
8	0·0363	0·0369	0·5	6	2½	60	+0·6

Bright, firmly-adhering deposits were obtained.

In experiments 1 to 6 potassium oxalate was used; in 7 and 8 ammonium oxalate was employed. In 5, 6 and 7 the mixture was strongly acid when the electrolysis was stopped.

V.—*Deposition from Solution in Potassium Cyanide.*

The solution is neutralised if necessary with potash, and a 20 per cent. solution of potassium cyanide is added until the precipitate redissolves. A large excess of cyanide is to be avoided.

Experiment	Zinc taken: grme.	Zinc found: grme.	$C.D._{100}$ Ampères	E.M.F. Volts	Time: hours	Error in mgrme.	c.c. KCN
1	0·2209	0·2213	0·5	8	6	+0·4	5·5
2	0·2175	0·2187	0·5	8	6	+1·2	6
3	0·2198	0·2209	0·5	8	7	+1·1	5
4	0·2173	0·2189	0·4	8	7	+1·6	7
5	0·0732	0·0728	0·4	8	4½	−0·4	5

A bright film is obtained which leaves a small quantity of black deposit undissolved when treated with acid. The residue collected from several analyses proved on examination to be carbon. The presence of carbon no doubt accounts for the high results obtained. The platinum electrodes are attacked by the cyanide in this and in the following process.

VI.—*Deposition from Solution of Zinc Phosphate in Potassium Cyanide.*

Moore recommends the precipitation of the zinc from sodium phosphate solution as rapid and complete. Potassium cyanide is added to the mixture to redissolve the precipitate. Ammonium carbonate is then added, and the mixture electrolysed at 80° C.

Experiment	Zinc taken: grme.	Zinc found: grme.	C.D.$_{100}$ Ampères	E.M.F. Volts	Time: hours	t° C.	Error in mgrme.
1	0·1630	0·1556	0·9	5·7	2	80	−7·4
2	0·2174	0·2091	1·53	7·8	2	80	−8·3
3	0·2174	0·2133	0·6−1·1	7·3	$2\frac{1}{2}$	80	−4·1
4	0·1451	0·1433	0·4	7·5	6	60	−1·8
5	0·1569	0·1564	0·33	7·5	$5\frac{1}{2}$	60	−0·5
6	0·2016	0·2023	0·4	7·5	6	60	+0·7
7	0·2175	0·2187	0·5	8·0	6	60	+1·2

Experiments 1 to 3 show that the precipitation is not complete in two and a half hours. The method cannot be considered rapid. The deposit is firm and bright. On solution in acids a small quantity of carbon remains.

VII.—*Deposition from Solution of Ammonium Lactate and Sulphate.*

Jordis recommends the addition of 5–7 grme. of ammonium lactate and 2 grme. of sulphate to the zinc salt. The solution is acidified with lactic acid, and the hot solution electrolysed in a platinum basin. A mechanical stirring arrangement should be used. The operation lasts about one hour and a half. The author states that when 0·3 grme. of zinc are used the error does not exceed 1 milligramme.

The following determinations were made without a stirring arrangement:—

Experiment	Zinc taken: grme.	Zinc found: grme.	C.D.$_{100}$ Ampères	Time: hours	Error in mgrme.
1	0·1571	0·1559	0·5−1	2	−1·2
2	0·2558	0·2558	0·5	2	0·0
3	0·1839	0·1850	0·5	2	+1·1
4	0·1813	0·1779	0·5	2	−3·4

Conclusions.—Both the methods in which potassium cyanide are used yield too high results and are objectionable on account of the action of the cyanide on platinum. Small quantities of zinc not exceeding 1 decigramme can be accurately determined by either of the three oxalate methods or by Brand's pyrophosphate process. For larger quantities of zinc Classen's oxalate process (IV.) in presence of free tartaric acid and Brand's method are recommended. These conclusions agree with Wolman's[1] as regards the accuracy of the oxalate methods and the inaccuracy of the Beilstein cyanide process, but differ as to the merits of Brand's pyrophosphate method, which Wolman condemns. Wolman also recommends Riché's method, in which a slight excess of ammonia is added to the zinc solution and the mixture acidified with acetic acid, C.D.$_{100}$ 0·1 − 0·2

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[1] *Zeits. Electro-Chem.*, 1897, **3**, 540.

ampere, 4 volts, 3 hours. He also obtained excellent results with the process of Vortmann and Foregger. Three grammes of pure caustic soda are added to the neutral zinc solution. At a temperature of 50°, with a current density of 0·5 to 1·5 amperes, the precipitation of the zinc is complete in one hour and a half.

The Determination of Nickel and Cobalt. (Part I.)

By HUGH MARSHALL, *D.Sc., F.R.S.E.*

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Author	Journal	Year	Vol.	Page	Composition of Electrolyte
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*Wrightson, F.	Zeits.anal.Chem.	1876	15	297	Ammonium hydrate
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*Thomälen, H.	Zeits.Electrochem.	1894	1	304	Ammonium sulphate and hydrate

* The references marked with an asterisk refer to both nickel and cobalt, the remainder to nickel only.

Of the various methods of determining nickel and cobalt electrolytically, that employing the sulphates in presence of ammonium sulphate and ammonia is by far the best known and most frequently employed. Next to it Classen's oxalate method and Brand's pyrophosphate method are probably those most frequently referred to. Of these three the former is, *primâ facie*, the preferable one, owing to the great simplicity of working it and the everyday character of the reagents employed, which are readily obtainable in a pure condition. Unless other methods can be shown to have a marked superiority in some important respect, we may assume that it will continue to be the general method for ordinary work, though the others might prove advantageous in special circumstances. The greater part of the investigation so far has therefore been devoted chiefly to a study of this method, and although only a limited number of experiments have been carried out with the other methods, the results obtained indicate that it is not excelled by any of the latter, for the determination of nickel.

The apparatus employed for most of the determination consisted of the usual cathode basins of about 200 c.c. capacity, roughened on their internal surface, with perforated anodes of watch-glass shape. In some experiments with small quantities of substance ordinary platinum crucibles were employed in place of the basins; in these cases a stout platinum wire coiled at the end served as anode.

The electrical measurements were made by means of Davies' ammeter and voltmeter, described in the third report of the Committee.[1]

When the large basins were employed the solutions were generally made up to a volume of 130–135 c.c. This left plenty of room for further additions, in case these should be found necessary, and the active cathode surface was then approximately 100 sq. cm., so that the ammeter readings corresponded to current density as generally stated. With the crucibles the volume was 18–20 c.c., and the cathode surface was roughly calculated to be 20–25 c.m.

The salts employed for analysis were generally the ammonium double sulphates, specially prepared for the purpose. Sometimes these were directly weighed out for each experiment, but solutions of known strength were also prepared, and measured quantities taken for various determinations. For some experiments the pure chlorides were employed. It was considered unnecessary to analyse the material by the other usual methods, as they are not more accurate than the electrolytic process. The results were simply judged relatively to one another, that result being considered best which gave the lowest percentage result, provided, of course, the metal was completely deposited in each case. Great attention was also paid to securing deposits of good general appearance, as a bright, lustrous, and firmly coherent deposit is always much more satisfactory and much less liable to be injuriously affected. A dark powdery-looking deposit was therefore considered unsatisfactory, even although the numerical result came out all right.

It is usually recommended to test for complete deposition by withdrawing, from time to time, portions of the liquid and adding hydrogen sulphide or potassium thiocarbonate. If this is done, however, the current must be continued for some time after no reaction is observed, otherwise a distinct quantity of metal may be left in solution. It was several times found that the whole volume of liquid after decantation gave a very distinct reaction, although none was visible when a small portion was tested. It was therefore considered more convenient to determine what time was necessary for average experiments conducted under suitable conditions, and to adhere to this generally, unless there were marked indications, for example in the rate of decolourisation, that deposition was not proceeding normally. The decanted liquid was always tested, and any case of incomplete deposition duly noted.

In the case of nickel the liquid can simply be poured off at the conclusion of the experiment, and the basin quickly rinsed with distilled water, as the deposit undergoes no apparent deterioration by such treatment, provided it is carried out quickly. In the case of cobalt it is not quite safe to work in this way, as the deposit is more liable to tarnish, and it is preferable, if the best results are desired, to employ the usual

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[1] Transactions, 1895.

siphon arrangement for decanting and washing without interruption of the current. After thorough rinsing with distilled water, and draining, the deposits were next treated with a few cubic centimetres of absolute alcohol, and finally dried in the steam oven. In each case the outside of the basin was carefully wiped clean and rubbed with chamois leather. Previous to beginning a determination the clean basins were not ignited, but treated in the same way as when they contained deposits, in order that the two weighings might be made under as nearly as possible similar conditions. It was found that basins, cleaned by hydrochloric acid and treated as above, fluctuated in weight both upwards and downwards on successive occasions. This at first seemed to indicate considerable liability to error, and yet very concordant results were obtained. The discrepancies would seem to be due to the difficulty of removing the last traces of a deposit by means of hydrochloric acid. It almost appears as if slight alloying took place, for the surface of the platinum becomes marked up to the level at which the liquid has stood during several experiments. From time to time the basins were cleaned as thoroughly as possible by means of nitric acid, ignition, treatment with concentrated hydrochloric acid, &c.

The substances to be added to the solution must of course be free from any metal which can be deposited electrolytically. Those employed were tested by means of ammonium sulphide and also by performing a blank experiment. Both the ammonium sulphate and the ammonia were employed in the form of '20 per cent.' solutions, i.e. 100 c.c. contained 20 grme. of substance. The required quantities were measured out approximately in graduated tubes or pipettes, and the total volume made up to 130 c.c., or whatever volume was desired, by adding the necessary quantity of distilled water.

Determination of Nickel.

The determination of nickel by the ammonium sulphate and ammonia method presents no great difficulty, and exceedingly good results are easily obtainable in ordinary circumstances. The first experiments were carried out in order to determine the general conditions under which the best results are obtained. From these the following were adopted as standard conditions for quantities of nickel ranging from 0·1 to 0·5 grme. or more, the volume of solution in that case being always about 130 to 135 c.c. :—

Substances added to Solution: 5 grme. of ammonium sulphate (25 c.c. of stock solution), and 5 grme. of ammonia (25 c.c. of stock solution).

Current: 0·5–0·8 ampere per 100 sq. cm. of cathode ; potential difference of electrodes 3–3·5 volts.

Temperature: Ordinary temperature of laboratory (15°–30°C. In warm weather the temperature rises to the latter amount by the heating effect of the current).

Time : $3\frac{1}{2}$–4 hours.

Under these conditions the metal is completely separated as a firmly adherent, well-coloured, and reguline deposit, entirely soluble in dilute hydrochloric acid. In appearance it differs but slightly from the interior surface of the basin. It undergoes no apparent change when left for several days exposed to air, and the weight also remains constant. In successive or simultaneous experiments results are frequently obtained differing by less than would correspond to 0·0001 grme. in the weight of the deposit.

Although the above conditions may be considered as practically ensuring a good deposit, it must not be supposed that they need always be strictly adhered to. Considerable latitude is allowable in certain respects. The influence which each factor exerts may next be considered.

If ammonium sulphate is omitted or added in insufficient quantity, the resulting deposit is dark and rough. The amount stated may be largely exceeded, however, without influencing the character of the deposit. The only effect which a considerable excess of ammonium sulphate seems to possess is possibly to make it slightly more difficult to completely remove the last traces of metal; that it does so is not quite certain.

The proportion of ammonia is more important. When nickel salts are electrolysed with a platinum or other non-soluble anode, nickelic hydroxide is formed on the anode. This does not take place if a sufficient quantity of free ammonia is present, hence the necessity for employing the amount stated. If much less is taken, a brownish-black deposit forms on the anode, and causes loss of nickel if not removed. If noticed, it must be dissolved by interrupting the current and adding more ammonia. If the experiment has been left unattended for the usual period of four hours, the formation of nickelic hydroxide involves prolonging the electrolysis for a further period till all the redissolved nickel is deposited. It is therefore much more satisfactory always to add sufficient ammonia at the beginning. The above-mentioned quantity may be exceeded by several grammes without very marked effect, but a greatly increased quantity retards deposition, and may cause an unequal deposit.

The quantity of ammonia which is necessary apparently depends chiefly on the strength of current employed, not so much on the amount of nickel present. During the electrolysis ammonia is neutralised at the anode, but with a weak current the partially neutralised liquid is replaced by fresh solution sufficiently rapidly to keep the liquid at the anode alkaline, even although there may not be a great amount of free ammonia present.

The current density may vary somewhat, but should not be greatly increased. If that is done, the deposit suffers in quality, being much rougher; the rate of deposition is increased, principally in the earlier stages. With a weaker current than that stated good deposits are still obtained, but the operation is more prolonged. When the quantity of metal to be deposited is not very great, a current density as low as 0·3 ampère may be employed, but it is advisable to decrease the quantity of ammonia (though not of ammonium sulphate) in that case. With a current density of 0·15 ampere it is not possible to get good deposits, even with small quantities of metal, if the usual quantity of ammonia is employed (*i.e.* 5 grme.); the metal forms irregular patches, and much remains in solution even after prolonged electrolysis. By diminishing the amount of ammonia to 1 grme., or even less, these drawbacks are practically removed. One grme. of free ammonia is sufficient to prevent formation of nickelic hydroxide with the last-mentioned current, even when the quantity of nickel is considerable, say 0·2 grme. For most of the experiments in the latter part of this investigation, using 0·15—0·2 grme. of nickel, a current density of 0·6—0·7 ampère was adopted as generally the most suitable.

There is no special advantage in conducting nickel determinations at temperatures higher than the ordinary. Deposition is then somewhat more rapid, but sometimes less regular, and the quality of the deposit is apt to suffer. As such determinations require more frequent attention than is the case with cold solutions, it is much more convenient to employ the latter.

The time stated is sufficient for all ordinary quantities of metal under the other conditions given. For small quantities it may be curtailed somewhat, but it is preferable rather to reduce the current and the proportion of ammonia. Even when the quantity of metal is considerable, the great bulk of it is deposited in a relatively short time, and it is the removal of the last portions which prolongs the duration of the experiment.

In connection with the electrolysis of nickel sulphate solutions, the formation of nickel sulphide has sometimes been noted, becoming evident when the deposit is dissolved in dilute hydrochloric acid, as a slight black insoluble residue. Though this was observed in several experiments, it was not possible to fix the particular conditions which determine it. Apparently it is not formed to any appreciable extent under the general working conditions specified above.

Where it is possible to select the quantity of metal to be used in a determination 0·15 to 0·2 grme. will be found to be very convenient. For many purposes, however, the quantity available may be much less than that. In dealing with small quantities there is no need to employ the ordinary large electrolytic basins unless a large volume of solution cannot well be avoided. Very good determinations can be carried out in ordinary platinum crucibles. In that case the quantity of ammonium sulphate and of ammonia should bear the same proportion to the volume of the solution as when the ordinary apparatus is employed. With a crucible holding about 20 c.c. of solution that would mean barely one gramme of ammonia and of ammonium sulphate, while the current to correspond would be about 0·15 ampère. It has been found that in this way deposition is more rapid than when working with a large volume of solution containing the same quantities of metal and ammonia, and with the same actual current (*not* same current density). When working on a small scale with small quantities of metal, there is, of course, less liability to accidental errors, owing to the more compact nature of the deposit, and the greatly diminished size of the vessel to be handled.

Numerous experiments have been carried out in order to determine the influence which may be exerted by other substances present in the solution during electrolysis; partly to discover if any are decidedly beneficial, but chiefly to find out those which are distinctly objectionable.

Potassium or sodium sulphate cannot be employed in place of the ammonium salt without very considerably lowering the character of the resulting deposits; they are invariably dark and rough, but with care the numerical results are hardly, if at all, affected. The presence of these salts, however, is not of itself harmful, for perfectly good deposits can be obtained by employing ammonium sulphate along with them in the usual manner.

Until recently it was quite generally stated that the *presence of chlorides* in the solution was objectionable, but this has been contradicted by F. Oettel,[1] and the present experiments fully confirm his result. *Ammonium chloride* may be added in considerable quantity along with the sulphate, or it may be employed in place of it; the resulting deposits and the numerical results obtained are in all cases excellent. There is a point to

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[1] *Zeits. Electrochem.*, 1894, p. 194.

be noted, however. In several experiments with chloride present it was found that there was deposition of nickelic hydroxide on the anode, although the normal quantity of ammonia was employed. This is probably due to the destruction of ammonia at the anode in this case, over and above that lost by neutralisation. If the discharged chlor-ions act like free chlorine, we can compare the action with sulphate and with chloride, as represented by the equations—

$$12NH_3+6SO_4+6H_2O=6(NH_4)_2SO_4+3O_2$$
$$16NH_3+12Cl=12NH_4Cl+2N_2$$

Assuming that these are the only actions which take place, it is evident that for the same quantity of current the quantity of free ammonia lost is one-third greater with the chloride. It is therefore advisable in this case to increase the amount of ammonia to 6 to 7 grme., unless a weaker current is employed.

In cases where nickel is to be deposited from a solution originally containing chloride only, ammonium chloride might perhaps be employed with advantage in place of ammonium sulphate. The formation of sulphide would then be quite impossible.

Nitrates, unless present only in small quantity, should be destroyed previous to electrolysis, as their presence considerably retards the deposition of the metal. This is evident from the much longer time necessary to decolourise the solution. In course of time the nitrate becomes reduced by the current, and the deposit ultimately obtained is perfectly good, being, in fact, exceptionally lustrous in appearance.

The presence of *phosphates* in the solution is immaterial, provided the precipitation of nickel phosphate is avoided when the ammonia is added. To reduce the risk of precipitation, the ammonia should be added last of all, after the ammonium sulphate and water, and it can be taken that it is all quickly mixed with the liquid. Perfectly good results may also be obtained by using ammonium phosphate alone in place of the sulphate.

What has been said of phosphate applies equally to *arsenate*, a matter of considerable importance in connection with the assay of nickel ores. There is apparently not the slightest reduction to arsenite, which would undergo further reduction to arsenic. The decanted liquid gives no trace of an immediate precipitate on the addition of hydrochloric acid and hydrogen sulphide.

The presence of *arsenite* is wholly inadmissible, as in that case the deposit is quite black, powdery, very loosely coherent, and contains large quantities of arsenic. If it is desired to determine nickel in solutions containing arsenic compounds, it is therefore necessary either to completely oxidise them or to remove them previous to electrolysis.

Chromates have a very marked and striking effect. The presence of a very small quantity completely prevents deposition, even when electrolysis is continued for a long time. When present it would therefore be necessary to get rid of them by one of the ordinary methods before proceeding to determine the nickel electrolytically.

The addition of sulphites to baths for electroplating with nickel has been recommended, and experiments were tried with varying quantities of *ammonium sulphite* present in solution. The resulting deposits are exceedingly bright and lustrous, but this seems to be the only advantage. An excessive quantity retards deposition somewhat, so that there is no practical benefit attending the use of sulphite for analytical work. This applies also to the employment of *borax*, which is recommended as a constituent of some plating baths. In presence of it deposits of very good appearance are obtained, though not so brilliant as in the case of sulphite, and the results are otherwise quite normal.

Nickel Determinations in Nickel Ammonium Sulphate.

No.	Weight of Salt taken. Grme.	Reagents added in Grammes	Volume of Solution C.C.	Current CD_{100} Ampère	E.M.F. Volts	Temp. ° C.	Time. Hours	Weight of Deposit. Grme.	Per Cent.	Nature of Deposit	Remarks
1	1·0701	5 Am_2SO_4 5 Amm.	130	0·7–0·6	3·3–3·8	13–20	4	0·1571	14·66	Very good	—
2	2·7372	„	„	0·8–0·7	3·1–3·3	12–20	3½	0·4018	14·68	Good	Slight reaction
3	5·4462	„	„	0·7–0·6	3·1–3·4	14–20	4½	0·8002	14·69	Rough, dark	„ „
4	0·5300	„	„	0·7–0·6	2·7–3·2	13–22	4	0·0780	14·72	Fair	—
5	0·1966	„	„	0·6–0·5	3·3–3·5	14–21	4½	0·0286	14·57	Very good	—
5a	0·1452	„	„	0·7–0·6	3·7–3·2	13–22	2	0·0210	14·46	„	Distinct reaction
6	1·1700	10 Am_2SO_4 5 Amm.	„	0·7–0·6	2·9–3·3	12–21	4	0·1717	14·67	„	—
7	1·0134	15 Am_2SO_4 5 Amm.	„	0·7–0·6	2·9–3·2	12–21	4	0·1487	14·67	„	—
8	1·1309	5 Am_2SO_4 5 Amm.	„	1·0	4·0	13–27	2¼	0·1663	14·71	Rough	Very slight reaction
9	1·2193	5 K_2SO_4 5 Amm.	„	0·7–0·6	3·6–4·0	12–22	4¼	0·1795	14·72	Dark, rough	—
10	1·3726	9 K_2SO_4 5 Amm.	„	0·7–0·6	3·3–3·7	12–20	4	0·2013	14·67	Very dark & rough	—
11	1·2959	5 Am_2SO_4 3 K_2SO_4 5 Amm.	„	0·7–0·6	3·1–3·5	14–22	4	0·1903	14·68	Very good	—
12	1·6255	3 Am_2SO_4 2 AmCl 5 Amm.	„	0·7–0·6	2·8–3·5	13–20	4¼	0·2391	14·71	Good	—
13	1·1033	5 AmCl 5 Amm. 1 „ later	„	0·7–0·6	2·9–3·6	12–21	4¼	0·1626	14·74	Very good	—
14	0·9420	6 Am_2SO_4 1 KNO_3 5 Amm.	„	0·7	3·2–3·4	11–22	5½	0·1378	14·63	Very good	Marked reaction
15	1·0116	5 Am_2SO_4 2 Am_2HPO_4 5 Amm.	140	0·7–0·6	3·5–4	13–22	4	0·1486	14·69	Very good	—
16	1·0738	5 Am_2HPO_4 6 Amm.	130	0·7–0·6	3·5–4	11–23	4¼	0·1580	14·71	Very good	—
17	1·1428	3 Am_2SO_4 2 Am_2HAsO_4 5 Amm.	„	0·7–0·6	3·6–4	12–22	4	0·1677	14·67	Very good	—
18	1·3833	5 Am_2SO_4 2 Am_2HAsO_4 5 Amm.	140	0·8–0·7	3·2–3·8	19–30	4	0·2032	14·69	Very good	—
19	1·1365	5 Am_2SO_4 5 Amm. 1 Am_2SO_3	130	0·7–1·0	3·6–4·1	10–22	2½	0·1671	14·70	Very good	Distinct reaction
20	1·2097	10 Am_2SO_3 5 Amm.	„	0·9–1·7	3·1–3·7	13–23	4¼	0·1794	14·83	Very good	—
21	1·1775	4 Am_2SO_4 2 $Na_2B_4O_7$ 5 Amm.	„	0·7–0·6	3·4–3·9	15–24	4	0·1732	14·71	Very good	—
22	1·3827	5 Am_2SO_4 1 $Am_2Cr_2O_7$ 5 Amm.	„	0·8–0·7	3–3·3	12–22	4¾	0·0003	—	No metal deposited	—
23	0·9431	5 Am_2SO_4 0·01 K_2CrO_4 5 Amm.	„	0·7–1·1	3–3·5	11–26	4	—	—	„	—
24	1·4621	5 Am_2SO_4 1 $MgSO_4 7H_2O$ 5 Amm.	„	0·7–0·6	3·3–3·8	10–22	4¼	0·2149	14·70	Dull, but good	Faint reaction

The employment of various *organic salts* in the determination of nickel has sometimes been recommended, but, generally speaking, the presence of organic substances in the solution appears to be objectionable. In some cases (*tartrates* or *citrates*, for example) the resulting deposits are of very good external appearance, but frequently the numerical results are high and the deposits leave a distinct brownish residue when dissolved in dilute acid ; further, the presence of considerable quantities of organic salts may retard deposition. This apparently does not apply to *oxalates*. While, on the whole, the use of organic salts, in dealing with ordinary straightforward depositions, appears to be attended with no real benefit, but in some cases the reverse, it is quite possible that they may be employed with advantage in certain separations.

The influence of salts of the alkali metals when present in the solution has already been discussed. It is sometimes stated that the presence of *magnesium salts* is objectionable, but this does not seem to be the case to any considerable extent, when only moderate quantities are present. The deposits obtained in the experiments tried were somewhat rougher than otherwise, and the results a trifle high.

The *metals of the alkaline earths* are of course excluded in presence of sulphate. Neither is it possible to determine nickel by deposition from solutions containing these metals by replacing the ammonium sulphate by the chloride. In that case alkaline liquid attracts carbonic anhydride from the air in sufficient quantity to give a distinct deposit of carbonate, so that the results obtained are much too high.

The examination of the behaviour of other metallic salts brings us to the question of the electrolytic separation of nickel from other metals, which will not be discussed fully here. It may be stated generally, however, that those metals which yield ammoniacal solutions are deposited electrolytically along with nickel. The most important of these are *copper and zinc*. The former can be removed by electrolysis in acid solution. The presence of even a relatively small quantity of zinc greatly retards the deposition of nickel, but ultimately both metals are completely removed from solution.

Determination of Cobalt.

The electrolytic estimation of cobalt has apparently not been the subject of so much investigation as that of nickel ; it is generally stated to be exactly similar in method to that of nickel, no further instructions being given. There is, however, a very considerable difference in the two cases. Good nickel deposits are obtainable with the greatest ease, but the reverse is the case with cobalt, and the best conditions for depositing the one are by no means the best for the other.

If an experiment with cobalt is conducted under the standard conditions given for nickel, the metal is not completely precipitated, and a very poor deposit is obtained. Apparently ammonia has a much greater effect in this case than with nickel, probably due to the formation of stable cobalti-ammonium compounds. On the other hand, the tendency to form cobaltic hydroxide on the anode is not nearly so great, and the quantity of ammonia can be reduced as low as 1·5 grme. Even then, four hours is barely sufficient for complete deposition with moderate quantities of metal, using cold solutions.

The best determinations obtained even with small quantities were very much inferior to those of nickel as regards the physical character of the deposit, and an extended series of experiments was carried out in the hope of securing the metal in better condition. These experiments varied considerably as regards the composition and proportions of the reagents employed, the current density, &c., but they led to no marked improvement. It had been decided to adopt 5 grme. of ammonium sulphate and 1·5 grme. of ammonia to 130 c.c. of liquid as the standard solution, and the influence of other substances present was being investigated as in the case of nickel, when, quite unexpectedly, a solution of the problem was indicated. The influence of nitrates was being studied, in the expectation that it would be at least as marked as with nickel, probably more so. This was found to be the case, 1 grme. of ammonium nitrate was sufficient to prevent the decolourisation of the solution even when the current was passed for several hours longer than would otherwise have been necessary. The experiment was continued overnight, and in the morning the solution was found to be quite decolourised, and on decantation proved to be free from cobalt. The deposit was bright and lustrous, much superior to any formerly obtained, but not so white as a good nickel one. Most important of all, the percentage result, which in former cases with complete precipitation varied mostly from 15·05 to 15·10, had in this case fallen to 14·90.

Acting on this, experiments were conducted with varying quantities of ammonium nitrate, when it was found that satisfactory results were obtained with only 0·2 grme. of the salt, but that less was not of much benefit. The presence of nitrate of course increases the time necessary for complete deposition, but, if so desired, this can be counteracted by conducting the electrolysis at a higher temperature, say about 60° C. A good deposit can still be secured when that is done, and the duration of the experiment need not exceed about four hours. If time is no object the electrolysis may still be conducted at the ordinary temperature, and even a larger quantity of ammonium nitrate employed.

Assuming that it is desired to keep the time limit fairly low, the following may be taken as standard conditions for quantities of cobalt, from 0·1—0·3 grme., the volume of solution, as usual, being about 130 c.c.

Reagents added: 5 grme. of ammonium sulphate, 2 grme. of ammonia, and 0·2 grme. of ammonium nitrate.

Current: 0·5—0·8 ampère per 100 sq. cm. of cathode surface; 3—3·5 volts.

Temperature: About 60° C.

Time: 4 hours.

The deposits obtained under these conditions are generally fairly good, but there is not the same regularity of results that is obtainable with nickel. The metal in this case is much more readily altered by various reagents, and greater care is necessary in the treatment of the deposit. As already stated, it is advisable to remove the liquid and wash the basin, in the first instance, by means of siphons without breaking the circuit.

As in the case of nickel, an excess of ammonium sulphate is comparatively unimportant, though in some of the earlier experiments, conducted at ordinary temperature without nitrate, it seemed as if the last traces were more difficult to remove in presence of much of this salt.

The amount of ammonia is more important here than in the case of nickel, as already indicated, the latter metal being apparently less liable to attack by ammoniacal solutions than cobalt. The proportion of ammonia should therefore be kept as low as possible, not only because the necessary time is thereby diminished, but also because better and more regular deposits are secured. The quantity stated above is greater than that formerly mentioned, because there is a greater loss with warm solutions than at the ordinary temperature.

The temperature should not be allowed to rise too high, otherwise irregular deposits may result, and there may be excessive loss of ammonia. A very small flame is sufficient to keep the liquid warm enough.

In dealing with small quantities the remarks made with reference to nickel apply with greater force here; for accurate results the quantity of ammonia and strength of current should both be moderated, or the whole experiment carried out on a reduced scale. Thus, it was found that a certain volume of cobalt solution which gave 0·0612 grme. of cobalt when electrolysed in a large basin in the usual way, gave only 0·0601 grme. in a simultaneous determination carried out on a reduced scale in a platinum crucible; although deposition was quite complete in the latter case, the result is decidedly lower, and this is explained by the fact that the deposit was entirely soluble in hydrochloric acid while the former left a slight black residue. A similar pair of experiments at another time gave 0·0603 and 0·0595 grme. respectively, again showing an advantage in favour of the crucible experiment.

The influence of other substances present in the solution is in many cases similar on the whole to what was found to be the case with nickel. There are, however, some exceptions to be noted in this respect.

In the early cobalt experiments without nitrate, *ammonium chloride* was occasionally tried in place of sulphate, and the results thus obtained seemed generally superior. One of the best results obtained was got by employing 10 grme. of ammonium chloride and 2 grme. of ammonia. It was found, however, that solutions containing both chloride and nitrate were rather erratic in their behaviour, sometimes giving very poor and irregular deposits. It is also more difficult to regulate the quantity of ammonia in such cases. If it is desired to determine cobalt in a solution containing ammonium chloride, it would appear preferable to conduct the electrolysis without the addition of ammonium nitrate.

The most striking difference from nickel is shown when cobalt solutions are electrolysed in presence of *arseniate*. We have seen that the presence of ammonium arseniate in large quantity has no effect on the nickel deposit. This is far from being the case with cobalt. Deposition is retarded, the deposit is very dark and rough, and the numerical result is far too high. The deposit contains a large quantity of arsenic, but the solution is apparently free from arsenite. Metallic cobalt would appear to be readily attacked by ammoniacal arseniate solution, which is probably reduced to arsenite. But any arsenite formed would be promptly reduced electrolytically to arsenic, which would contaminate the deposit.

Another point which shows how unsafe it is to assume that what holds for nickel does so also for cobalt is the behaviour in presence of *zinc salts.* This comes into the domain of separations, but it may be mentioned here. With small quantities of zinc in presence of nickel, the deposit obtained by the usual method contains the whole of both metals, as already noted. In the case of cobalt a solution containing zinc gives on electrolysis by the ordinary method a deposit which is not very good in appearance, but is practically normal as regards numerical result. The decanted liquid gives a pure white precipitate of zinc sulphide on the addition of hydrogen sulphide. To what extent, if at all, this difference depends on the somewhat different conditions prevailing in the two kinds of experiments has not yet been investigated.

Chromates completely prevent precipitation as with nickel.

With some *organic salts*, *tartrates* for example, the deposits are of very good appearance, but the results are apt to be too high, as in the case of nickel.

Cobalt Determinations in Cobalt Ammonium Sulphate.

No.	Weight of Salt taken. Grme.	Reagents added in Grme.	Volume of Solution C.C.	Current $C.D._{100}$ Ampère	E.M.F. Volts	Temp. ° C.	Time. Hours	Weight of Deposit. Grme.	Per Cent.	Nature of Deposit	Remarks
1	1·2740	5 Am_2SO_4 5 Amm.	130	0·68	3·8	13–25	4½	0·1905	14·95	Dark and irregular	Very distinct reaction
2	1·3660	,,	,,	0·5–0·7	3·7–4·0	,,	,,	0·2013	14·74	Bad, black	Very marked reaction
3	0·5344	,,	,,	,,	,,	,,	,,	0·0775	14·50	,,	,,
4	1·2264	5 Am_2SO_4 2 Amm.	,,	0·7–0·6	3·8	,,	4	0·1838	14·99	Poor	Slight reaction
5	0·8845	10 Am_2SO_4 2 Amm.	,,	,,	3·7	,,	,,	0·1327	15·00	,,	,,
6	1·3488	10 Am_2SO_4 6 Amm.	,,	0·75–0·7	3·7–3·4	13–30	5	0·1847	13·69	,,	Very marked reaction
7	1·4139	5 Am_2SO_4 1 Amm. 0·4 ,, *later*	,,	0·8–0·7	3·9	11–27	4	0·2129	15·06	Fair	Very slight reaction
8	1·0189	5 Am_2SO_4 5 Amm.	,,	1·3	5–4·2	15–45	3½	0·1526	14·98	Dark, poor	Distinct reaction
9	1·5960	5 Am_2HPO_4 2 Amm.	,,	0·8–0·7	4–3·7	17–40	4	0·2102	15·05	Poor	Very distinct reaction
10	1·0027	10 AmCl 2 Amm.	,,	0·8–0·85	3·3	15–30	,,	0·1501	14·97	Fair	No reaction
11	1·3011	5 Am_2SO_4 1·5 Amm.	,,	0·7–0·6	3·1–3·4	45–55	3¾	0·1963	15·09	Dark	,,
12	1·9674	5 Am_2SO_4 1·5 Amm.	,,	,,	3–3·6	45–50	,,	0·2950	15·00	,,	,,
13	1·1169	5 Am_2SO_4 1·5 Amm. 1·0 $AmNO_3$	,,	0·7–0·68	3·5–4	16–30	24	0·1664	14·90	Very good	,,
14	1·4069	5 Am_2SO_4 2 Amm. 0·2 $AmNO_3$	,,	0·75–0·7	3·1–3·5	60–80	4	0·2092	14·87	,,	,,
15	1·1443	5 Am_2SO_4 2 Amm. 0·1 $AmNO_3$	,,	0·7–0·6	3·6–4	16–30	5¾	0·1707	14·92	Dark	,,
16	1·3728	5 Am_2SO_4 2 Amm. 0·2 $AmNO_3$	,,	0·8–0·6	3·4	60–70	4	0·2053	14·95	Good, rough	,,
17	0·3682	,,	,,	,,	,,	,,	,,	0·0554	15·05	Very good	,,
18	1·0001	,,	,,	0·72	3·1–3·3	50–60	,,	0·1503	15·03	Fairly good	,,
19	1·0001	,,	,,	0·7–0·6	3·0–3·4	,,	,,	0·1497	14·97	Good	,,
20	3·0207	,,	,,	0·65	3·1	60	4½	0·4535	15·01	Fair	Deposit not all soluble
21	0·4028	,,	,,	0·6–0·7	3·2–3·5	60–70	3½	0·0612	15·19	,,	,,
22	0·4028	0·8 Am_2SO_4 0·4 Amm. 0·03 $AmNO_3$	19	0·7–0·5	3·2	50	,,	0·0601	14·92	,,	Deposit all soluble
23	1·0001	5 Am_2SO_4 2 Amm. 0·2 $AmNO_3$ 2 Am_2HAsO_4	130	0·6	,,	40–60	4	0·1691	—	,,	Partly insoluble. Compare weight in 19
24	1·0001	5 Am_2HAsO_4 2 Amm.	,,	,,	3·1	50–65	,,	0·1723	—	Black and spongy	,,
25	1·0001	5 Am_2SO_4 2 Amm. 0·2 $AmNO_3$ $2MgSO_4,7H_2O$	,,	,,	2·8–3·1	60–70	4½	0·1511	15·11	Fairly good	Left slight residue

Other Electrolytic Methods.

As already stated, the great majority of the experiments so far carried out have dealt with the ammonium sulphate and ammonia method, as it seems on the whole preferable for ordinary simple determinations. The further investigation of other methods will be conducted more from the point of view of their application to special cases, such as separations.

The tabulated experiments given in this paper are only a small portion of those obtained, as experiments were often repeated under similar or slightly varying conditions, so that general opinions might be more confidently formed. In the case of cobalt especially the total number of experiments was considerable, owing to the much greater difficulty of obtaining deposits which were really satisfactory. The selection has not been made so as simply to give a series of the most concordant results, but may be taken as fairly representative.

In conclusion, I have to express my indebtedness to my brother, Mr. Ralph Marshall, for assistance in carrying out the routine work of numerous experiments during the latter part of the investigation.

Isomeric Naphthalene Derivatives.—Report of the Committee, consisting of Professor W. A. TILDEN *(Chairman) and* Dr. H. E. ARMSTRONG *(Secretary).*

ALTHOUGH it is established that when betanaphthol is acted on by bromine, at first bromine enters the hydroxylated nucleus in position 1, and in the second place the non-hydroxylated ring in position 3′, the structure of tribromonaphthol remains undetermined; but it is certain that the third bromine atom is introduced either into position 3 or into position 4, as both these are occupied in tetrabromonaphthol.

Considerable difficulty has been experienced in settling this point. Meanwhile, in extending the inquiry, in order to obtain complete information of the influence on substitution exercised by the OH group in betanaphtnol, the discovery has been made that the two possible homonucleal forms of tribromonaphthol are both produced when betanaphthol is acted upon by three molecular proportions of bromine. The crude product cannot be directly purified, but by converting it into acetate and repeatedly extracting this with boiling acetone, about half is dissolved; the residue almost entirely consists of the acetate, of the tribromobetanaphthol already described by Armstrong and Rossiter. A further quantity of this acetate is obtained by fractionally crystallising the solution, and also about 15 to 20 per cent. of the acetate of a new tribromobetanaphthol. Although the two isomerides resemble each other very closely, and cannot be directly separated, their derivatives differ considerably; thus—

		A. and R.	New
		°	°
Tribromobetanaphthol	m.p.	155	159
,, ,, acetate	,,	184	149
,, ,, benzoate	,,	187	164
Nitrodibromobetanaphthol	,,	156	163
Dibromobetanaphthaquinone	,,	150	187

The comparative investigation of the dibromonaphthoquinones obtained from the tribromonaphthols and other sources is being undertaken with the object of determining their constitution and that of the naphthol derivatives from which they are prepared. That melting at 171°, obtained as the principal product of the action of nitric acid on dibromobetanaphthol, is converted by alkali into a dibromohydroxyalphanaphthoquinone, and therefore does not contain a bromine atom in position 4. As the dibromoquinone melting at 150°, obtained from the tribromonaphthol melting at 155°, is converted by alkali into a condensation product, it appears probable that the tribromonaphthol from which it is derived is the 1 : 2 : 4 : 3′ compound. The writer is indebted to Mr. W. A. Davis for carrying out these experiments.

Mr. Davis has obtained interesting results by comparatively studying the amounts of ether formed on boiling the various naphthol derivatives with alcohol and sulphuric acid. Whilst betanaphthol gives as much as 85 per cent. of the amount of ether indicated by theory, 1 bromobetanaphthol yields only about 10 per cent., and an even smaller proportion is obtained from 1 : 3′ dibromobetanaphthol, although 3′ bromobetanaphthol yields about 70 per cent. of the theoretical amount of ether. A single chlorine atom in position 1 exercises about the same influence as a single bromine atom, but 1 : 3 dichlorobetanaphthol and the tribromonaphthol melting at 155° are entirely unaffected by boiling with alcohol and sulphuric acid.

The Promotion of Agriculture.—Interim Report of the Committee, consisting of Sir JOHN EVANS (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Professor M. FOSTER, Professor MARSHALL WARD, Sir J. H. GILBERT, Right Hon. J. BRYCE, Professor J. W. ROBERTSON, Dr. W. SAUNDERS, Professor MILLS, Professor J. MAVOR, Professor R. WARINGTON, Professor POULTON, *and* Mr. S. U. PICKERING, *appointed to report on the Means by which in Various Countries Agriculture is advanced by Research, by Special Educational Institutions, and by the Dissemination of Information and Advice among Agriculturists.*

THE Committee was appointed at the Toronto Meeting, largely in consequence of the deep impression produced by the visits paid by members of the Association to the Canadian Agricultural Experimental Stations, and by the evidence there afforded of the value of the support given by the Government to Agriculture. The object in view is to prepare an account of the work done in Canada, in the United States of America, and in Europe in promoting Agriculture by special educational institutions, by research, by experimental demonstrations, and by the dissemination of information among farmers and others. Such an account will serve to draw attention by contrast to the backwardness of this conntry in such matters, and to the directions in which it is desirable that efforts should be made. The task is necessarily a difficult one, as it involves the collection and discussion of the very extensive literature of the subject, besides much personal inquiry. Although much information has already been collected it is not yet possible to present a report that will effect the desired purpose ; nor was it supposed that such a report could be prepared within a year. It is therefore requested that the Committee be reappointed.

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. Roscoe (*Chairman*), Dr. Marshall Watts (*Secretary*), Sir J. N. Lockyer, Professor J. Dewar, Professor G. D. Liveing, Professor A. Schuster, Professor W. N. Hartley, Professor Wolcott Gibbs, *and* Captain Abney.

Iron (Spark Spectrum).

Exner and Haschek: 'Sitzungsber. kais. Akad. Wissensch. Wien.,' cvi. 1897.

The measurements of Kayser and Runge are in the *arc* spectrum.

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
(4736·96)	1	4736·96 Rowland	1·30	5·8	21104·8
4710·45	1	4710·37 K. & R.	1·29	,,	21223·6
4707·50	1	4707·45 ,,	,,	5·9	21236·8
4691·60	1	4691·52 ,,	1·28	,,	21308·8
4679·02	1	4678·97 ,,	,,	,,	21366·1
4673·4	1n	4673·29 ,,	,,	,,	21392
4669·4	1n	4669·30 ,,	,,	,,	21410
4668·30	1	4668·23 ,,	,,	,,	21415·2
4667·62	1n	4667·56 ,,	,,	,,	21418·3
4647·62	1	4647·54 ,,	1·27	,,	21510·5
4638·20	1	4638·13 ,,	,,	,,	21554·2
4637·70	1	4637·66 ,,	,,	,,	21556·5
4635·50	1n		,,	,,	21566·7
4633·06	1	4633·02 ,,	,,	6·0	21578·0
4629·51	1	4629·44 ,,	,,	,,	21594·6
4625·22	1	4625·19 ,,	,,	,,	21614·6
4619·45	1	4619·40 ,,	,,	,,	21641·6
4613·45	1n	4613·35 ,,	1·26	,,	21669·8
4611·45	1	4611·38 ,, 11·437 R.	,,	,,	21679·2
4607·73	1	4607·79 ,,	,,	,,	21696·7
4603·11	2	4603·03 ,,	,,	,,	21718·4
4598·31	1	4598·26 ,,	,,	,,	21741·1
4595·56	1	4595·48 ,,	,,	,,	21754·1
4592·83	1	4592·75 ,,	,,	,,	21767·1
4584·01	4	4583·93 ,,	,,	,,	21809·0
4576·48	1		1·25	,,	21844·9
4556·25	1	4556·22 ,,	,,	6·1	21941·8
4556·04	1		,,	,,	21942·8
4554·20	1 Ba	4554·16 ,,	,,	,,	21951·7
4552·72	1n	4552·66 ,,	,,	,,	21958·8
4549·65	3	4549·57 ,,	,,	,,	21973·6
4548·00	2	4547·95 ,,	,,	,,	21981·6
4541·68	1	4541·43 ,,	1·24	,,	22012·2
4531·32	2	4531·25 ,,	,,	,,	22062·5
4529·80	1n	4529·75 ,,	,,	,,	22069·9
(4528·80)	6	4528·78 ,, 28·80 R.	,,	,,	22074·8
4525·31	2	4525·27 ,,	,,	,,	22091·8

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4522·80	2	4522·72 K. & R.	1·24	6·1	22104·1
4520·41	1	4520·35 "	"	"	22115·8
4517·68	1	4517·64 "	"	"	22129·2
4515·49	1	4515·36 "	"	"	22139·9
4514·31	1	4514·29 "	"	"	22145·7
4508·42	2	4508·40 "	"	"	22174·8
4494·74	5	4494·67 " 94·725 R.	12·3	6·2	22242·0
4491·58	1	4491·53 ..	"	"	22257·7
4490·93	1n	4490·88 "	"	"	22260·9
4490·24	1	4490·19 "	"	"	22264·3
4489·88	1	4489·84 "	"	"	22266·1
4489·34	1n	4489·08 "	"	"	22268·8
4488·3	1b	4488·26 "	"	"	22274
4485·82	1	4485·77 "	"	"	22286·3
4484·40	2	4484·36 "	"	"	22293·3
4482·94	1	4482·86 "	"	"	22300·6
4482·40*	4	4482·35 "	"	"	22303·3
4480·31	1	4480·26 "	"	"	22313·7
4479·76	1	4479·73 "	"	"	22316·4
4476·19	5	4476·20 "	"	"	22334·2
4469·54	2	4469·53 "	"	"	22367·5
4466·70	5	4466·70 "	1·22	"	22381·7
4464·91	1	4464·88 "	"	"	22390·7
4462·15	1n	4462·11 "	"	"	22404·5
4461·80	3	4461·75 "	"	"	22406·3
4459·28	4	4459·24 "	"	"	22418·9
4458·22	1n	4458·35 "	"	"	22424·3
4456·46	1	4456·46 "	"	"	22433·1
4454·89	1		"	"	22441·0
4454·53	2	4454·50 "	"	"	22442·9
4451·70	1n	4451·71 "	"	"	22457·1
4450·46	1	4450·44 "	"	"	22463·4
(4447·90)	3	4447·85 " 47·90 R.	"	"	22476·3
4443·35	3	4443·30 "	"	"	22499·3
4443·00	1	4442·97 "	"	"	22501·1
4442·51	4	4442·46 "	"	"	22503·6
4440·05	1	4439·96 "	"	"	22516·1
4438·50	1	4438·50 "	"	"	22523·9
4437·06	1	4437·04 "	"	"	22531·2
4435·31	1	4435·27 "	"	"	22540·1
4435·20	1		"	"	22540·7
4433·97	1	4433·98 "	"	"	22547·0
4433·39	2	4433·32 "	"	"	22549·9
4432·73		4432·68 "	"	"	22553·3
4430·79	2	4430·74 "	1·21	6·3	22563·0
4430·35	1	4430·32 "	"	"	22565·3
4427·49	3	4427·44 "	"	"	22579·9
4424·6	1b	4424·26 "	"	"	22595
4422·74	3	4422·67 "	"	"	22604·1
4419·93	1		"	"	22618·5
4419·70	1		"	"	22619·7
4415·98	1		"	"	22638·7
4415·29	8	4415·27 "	"	"	22642·3
4413·70	1		"	"	22650·4
4410·9	1b		"	"	22664·8

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
4409·44	1		1·21	6·3	22672·3
4409·34	1	4409·25 K. & R.	,,	,,	22672·8
4408·59	2	4408·54 ,,	,,	,,	22676·7
4407·89	2	*4407·80 ,, ·848 R.	,,	,,	22680·3
4405·65	1		,,	,,	22691·8
4404·94	10	4404·88 K. & R.	,,	,,	22695·5
4401·60	1		,,	,,	22712·7
4401·50	1	4401·46 ,,	,,	,,	22713·2
4400·55	1n		,,	,,	22718·1
4396·88	1n		,,	,,	22737·1
4392·50	1n		1.20	,,	22759·8
4391·15	1	*4391·152 R.	,,	,,	22766·8
4389·4	1n	4389·35 K. & R.	,,	,,	22776
4388·61	2	4388·57 ,,	,,	,,	22780·0
4388·07	2	4388·01 ,,	,,	,,	22782·8
4385·55	1	4385·40 ,,	,,	,,	22795·9
4384·39	2	4384·38 ,,	,,	,,	22801·9
4383·71	10	4383·70 ,,	,,	,,	22805·4
4382·96	1		,,	,,	22809·3
4379·40	1n	4379·36 ,,	,,	,,	22827·9
4376·96	1n	4376·89 ,,	1·20	6·3	22840·6
4376·10	4	4376·04 ,, ·102 R.	,,	,,	22845·1
4374·67	1	4374·59 K. & R.	,,	,,	22852·6
4373·74	1	4373·67 ,,	,,	,,	22857·4
4370·52	1	4370·59 ,,	,,	,,	22874·2
4369·96	3	4369·89 ,, ·946 R.	,,	,,	22877·2
4368·11	1	4368·00 ,,	,,	6·4	22886·8
4367·75	2	4367·68 ,,	,,	,,	22888·7
4366·13	1n	4366·02 ,,	,,	,,	22897·2
4361·5	1n		,,	,,	22921
4361·0	1n		,,	,,	22924
4358·68	1	4358·62 ,,	,,	,,	22936·3
4357·73	1n		,,	,,	22941·3
(4352·90)	3	4352·86 ,, ·910 R.	1·19	,,	22966·8
4351·89	2	4351·67 ,,	,,	,,	22972·1
4346·63	1	4346·66 ,,	,,	,,	22999·9
4343·80	1	4343·81 ,,	,,	,,	23014·9
4343·37	1	4343·39 ,,	,,	,,	23017·2
4338·89	1		,,	,,	23041·0
4338·39	1	4338·38 ,,	,,	,,	23043·6
4337·22	5	4337·14 ,,	,,	,,	23049·8
4334·55	1		,,	,,	23064·0
4330·35	1n		,,	,,	23086·4
4330·15	1n		,,	,,	23087·5
4328·02	1	4328·02 ,,	,,	,,	23098·9
4327·22	2	4327·22 ,,	,,	,,	23103·1
4326·87	1	4326·86 ,,	,,	,,	23105·0
4326·50	1		,,	,,	23107·0
4325·94	10	†4325·92 ,, ·982 R.	,,	,,	23110·0
4321·93	1	4321·90 ,,	,,	,,	23131·4
4321·67	1		,,	,,	23132·8
4321·55	1		,,	,,	23133·4
4320·92	1	4320·89 ,,	,,	,,	23136·8

* Double. † Triple.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4318·75	1	4318·78 K. & R.	1·18	6·4	23148·5
4315·26	5	4315·21 ,,	,,	,,	23167·2
4314·46	1	4314·43 ,,	,,	,,	23171·5
4312·88	1		,,	,,	23180·0
4312·48	1		,,	,,	23182·1
4312·31	1	4312·28 ,,	,,	,,	23182·4
4309·51	3	4309·50 ,,	,,	,,	23198·1
4309·16	2	4309·14 ,,	,,	,,	23200·0
4308·70	1		,,	6·5	23202·4
4308·06	10	G 4307·96 ,, ·023 R.	,,	,,	23205·8
4305·59	2	4305·58 ,,	,,	,,	23219·1
4304·76	1	4304·66 ,,	,,	,,	23223·6
4303·32	2	4303·25 ,,	,,	,,	23231·4
4302·67	1Ca	4302·68 ,,	,,	,,	23234·9
4302·32	1	4302·31 ,,	,,	,,	23236·8
4300·94	1	4300·86 ,,	,,	,,	23244·2
4299·43	7r	4299·42 ,,	,,	,,	23252·4
4298·17	1	4298·16 ,,	,,	,,	23259·2
4296·73	1	4296·56 ,,	,,	,,	23267·0
4295·12	1n	4295·08 ,,	,,	,,	23275·7
4294·32	6	4294·26 ,,	,,	,,	23280·1
4292·4	1b	4292·36 ,,	,,	,,	23290
4291·62	1	4291·69 ,,	,,	,,	23294·7
4291·05	1	4290·99 ,,	,,	,,	23297·8
4290·55	1	4290·50 ,,	,,	,,	23300·5
4290·08	1n	4290·04 ,,	,,	,,	23303·1
4289·47	1n	4289·84 ,,	,,	,,	23306·4
4289·0	1n	4289·08 ,,	,,	,,	23309
4288·27	1	4288·25 ,,	,,	,,	23312·9
4287·10	1n	4287·05 ,,	,,	,,	23319·3
4286·55	1	4286·58 ,,	,,	,,	23322·3
4285·56	2	4285·57 ,,	,,	,,	23327·7
4283·13	1	4283·20 ,,	,,	,,	23340·9
4282·60	6	4282·58 ,,	,,	,,	23343·8
4280·00	1	4279·99 ,,	1·17	,,	23358·0
4279·65	1	4279·59 ,,	,,	,,	23359·9
4278·33	1n	4278·35 ,,	,,	,,	23367·1
4277·6	1b		,,	,,	23371
4276·80	1	4276·80 ,,	,,	,,	23375·5
4276·27	1		,,	,,	23378·4
4276·11	1		,,	,,	23379·2
4274·02	1	4273·99 ,,	,,	,,	23390·7
4273·42	1		,,	,,	23394·0
4272·53	1	4272·61 ,,	,,	,,	23398·8
4271·93	10	4271·93 ,,	,,	,,	23402·1
4271·32	7	4271·30 ,,	,,	,,	23405·5
4269·90	1	4269·89 ,,	,,	,,	23413·2
4269·78	1		,,	,,	23413·9
4268·86	1	4268·87 ,,	,,	,,	23419·0
4267·95	2	*4267·97 ,, ·941 R.	,,	,,	23424·0
4267·68	1		,,	,,	23425·4
4267·56	1		,,	,,	23426·1
4267·08	1	4267·08 ,,	,,	,,	23428·7

* Double.

IRON—*continued.*

Wave length Spark Spectrum	Intensity and Character	Previous Measurements	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$—	
4265·35	1n	4265·37 K. & R.	1·17	6·5	23438·2
4264·85	1n	4264·88 ,,	,,	,,	23441·0
4264·34	1	4264·37 ,,	,,	,,	23443·8
4260·64	10	4260·64 ,,	,,	,,	23464·2
4259·07	1	4259·06 ,,	,,	,,	23472·8
4258·76	1	4258·75 ,,	,,	,,	23474·5
4258·40	1n	4258·43 ,,	,,	,,	23476·5
4256·40	1n	4256·32 ,,	,,	,,	23487·5
4255·61	1	4255·64 ,,	,,	,,	23491·9
4255·25	1		,,	,,	23493·9
4255·06	1	4255·08 ,,	,,	,,	23494·9
4254·45	1	4254·45 ,, ·499 R.	,,	,,	23498·3
4251·55	1		,,	6·6	23514·2
4250·95	8	4250·93 ,,	,,	,,	23517·6
(4250·30)	7	4250·28 ,,	,,	,,	23521·2
4248·37	1	4248·35 ,,	,,	,,	23431·8
4247·58	4n	4247·60 ,,	,,	,,	23536·2
4246·14	2	4246·18 ,,	,,	,,	23544·2
4245·32	3	4245·39 ,,	,,	,,	23548·8
4243·45	1	4243·44 ,,	1·16	,,	23559·1
4242·82	1	4242·85 ,,	,,	,,	23562·6
4240·46	1	4240·50 ,,	,,	,,	23575 7
4239·88	3	4239·90 ,,	,,	,,	23579·0
4238·90	4	4238·98 ,,	,,	,,	23584·4
4238·10	2	4238·14 ,,	,,	,,	23588·9
4237·22	1	4237·26 ,,	,,	,,	23593·8
4236·09	8	4236·09 ,,	,,	,,	23600·1
4233·74	6	4233·76 ,,	,,	,,	23613·2
4233·26	4	4233·25 ,,	,,	,,	23615·9
4231·9	1b		,,	,,	23623
4229·83	1	4229·86 ,,	,,	,,	23635·0
4229·58	1	4229·61 ,,	,,	,,	23636·4
4227·60	7	4227·60 ,,	,,	,,	23647·5
4226·88	5 Ca.	4226·84 ,,	,,	,,	23651·5
4226·53	1	4226·52 ,,	,,	,,	23653·5
4226·06	1	4226·08 ,,	,,	,,	23656·1
4225·57	3	4225·61 ,,	,,	,,	23658·8
4224·63	1	4224·63 ,,	,,	,,	23664·1
4224·26	3	4224·27 ,,	,,	,,	23666·2
4223·30	1	4223·40 ,,	,,	,,	23671·6
4222·35	4	4222·35 ,,	,,	,,	23676·9
4220·46	2	4220·44 ,,	,,	,,	23687·5
4219·51	6	4219·47 ,,	,,	,,	23692·8
4217·67	2	4217·69 ,,	,,	,,	23703·2
4216·29	2	4216·28 ,,	,,	,,	23710·9
4215·56	1	4215·52 ,,	1·16	,,	23715·0
4213·77	2	4213·75 ,,	,,	,,	23725·1
4210·52	5	4210·48 ,,	,,	,,	23743·4
4208·73	2	4208·71 ,,	,,	,,	23753·5
4207·26	2	4207·22 ,,	,,	,,	23761·8
4206·84	1	4206·78 ,,	,,	,,	23764·2
4206·33	1		,,	,,	23767·1
4205·69	1n	4205·63 ,,	1·15	,,	23770·7
4204·10	4	4204·07 ,,	,,	,,	23779·7
4202·86	1	4202·85 ,,	,,	,,	23786·7

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4202·20	9	4202·15 K. & R.	1·15	6·6	23790·5
4201·07	2	4201·01 ,,	,,	,,	23796·9
4200·13	1	4200 01 ,,	,,	6·7	23802·1
4199·27	8	4199·19 ,, ·254 R.	,,	,,	23807·0
4198·86	1	4198·75 ,,	,,	,,	23809·3
4198·50	6	4198·42 ,,	,,	,,	23811·3
4196·46	2	4196·66 ,,	,,	,,	23822·9
4195·75	1n	4195·71 ,,	,,	,,	23826·9
4195·50	3	4195·46 ,,	,,	,,	23828·4
4191·80	3n	4191·72 ,,	,,	,,	23849·4
4191·61	4	4191·57 ,,	,,	,,	23850·5
4188·00	7	4187·92 ,,	,,	,,	23871·1
4187·22	7	4187·17 ,,	,,	,,	23875·5
4185·03	4	4184·99 ,, ·054 R.	,,	,,	23888·0
4182·54	2	4182·46 ,,	,,	,,	23902·2
4181·94	7	4181·85 ,,	,,	,,	23905·6
4179·01	2	4178·95 ,,	,,	,,	23922·4
4178·16	1	4178·11 ,,	,,	,,	23927·3
4177·74	1	4177·66 ,,	,,	,,	23929·7
4176·70	2	4176·62 ,,	,,	,,	23935·6
4175·77	4	4175·71 ,,	,,	,,	23941·0
4175·06	1	4174·98 ,,	,,	,,	23945·1
4174·10	1	4174·00 ,,	,,	,,	23950·6
4173·59	2	4173·52 ,,	,,	,,	23953·5
4172·88	2	4172·81 ,,	,,	,,	23957·6
4172·29	3	4172·20 ,,	,,	,,	23961·0
4171·80	1	4171·79 ,,	,,	,,	23963·8
4171·05	3	4170·99 ,,	,,	,,	23968·1
4168·07	1	4167·96 ,,	1·14	,,	23985·2
4165·57	1n	4165·51 ,,	,,	,,	23999·6
4163·8	1n	4163·74 ,,	,,	,,	24010
4161·63	1n	4161·57 ,,	,,	,,	24022·3
4161·2	1n	4161·13 ,,	,,	,,	24025
4158·94	2	4158·89 ,,	,,	,,	24037·9
(4157·95)	2	4157·91 ,, ·936 R.	,,	,,	24043·6
4156·93	4	4156·88 ,,	,,	,,	24049·5
4154·92	3	4154·95 ,,	,,	,,	24061·2
4154·61	4	4154·57 ,,	,,	,,	24062·9
4154·10	3n	4154·04 ,,	,,	,,	24065·9
4152·32	1	4152·25 ,,	,,	,,	24076·2
4150·40	1	4150·42 ,,	,,	,,	24087·4
4149·49	2	4149·44 ,,	,,	,,	24092·6
4147·79	2	4147·74 ,,	,,	6·8	24102·4
4145·68	1n		,,	,,	24114·7
4145·45	1n	4145·29 ,,	,,	,,	24116·0
4144·62	1	4144·72 ,,	,,	,,	24120·9
4144·06	7	4143·96 ,,	,,	,,	24124·1
4143·54	5	4143·50 ,,	,,	,,	24127·2
4142·01	1	4141·94 ,,	,,	,,	24136·1
4140·02	1		,,	,,	24147·7
4139·85	1	4139·96 ,,	,,	,,	24148·7
4137·12	4	4137·06 ,,	,,	,,	24164·6
4136·68	1	4136·58 ,,	,,	,,	24167·2
4136·31	1		,,	,,	24169·3
4134·83	5	4134·77 ,,	,,	,,	24178·0

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4134·54	1	4134·50 K. & R.	1·14	6·8	24179·7
4134·03	1n	4133·96 ,,	,,	,,	24182·7
4133·73	1n	4133·67 ,,	,,	,,	24184·4
4133·05	4	4132·96 ,,	,,	,,	24188·4
(4132·24)	8	4132·15 ,,	,,	,,	24193·2
4128·89	1	4128·91 ,,	1·13	,,	24212·8
4127·92	1n	4127·86 ,,	,,	,,	24218·5
4127·74	3	4127·68 ,,	,,	,,	24219·5
4126·35	2	4126·25 ,,	,,	,,	24227·7
4126·05	1	4125·94 ,,	,,	,,	24229·5
4125·78	1	4125·71 ,,	,,	,,	24231·0
4123·90	1	4123·81 ,,	,,	,,	24242·1
4122·69	2	4122·59 ,,	,,	,,	24249·2
4121·99	2	4121·88 ,,	,,	,,	24253·3
4120·37	2	4120·28 ,,	,,	,,	24262·9
4118·72	5	4118·62 ,,	,,	,,	24272·6
4115·1	1n	4114·98 ,,	,,	,,	24294
4114·61	3	4114·53 ,, ·593 R.	,,	,,	24296·8
4113·14	1	4113·08 ,,	,,	,,	24305·5
4109·99	4	4109·88 ,,	,,	,,	24324·2
4109·23	1	4109·23 ,,	,,	,,	24328·7
4107·65	4	4107·58 ,, ·636 R.	,,	,,	24338·0
4106·60	1	4106·55 ,,	,,	,,	24344·2
4106·40	1	4106·37 ,,	,,	,,	24345·4
4104·32	1	4104·20 ,,	,,	,,	24357·8
4101·73	1	4101·76 ,,	,,	,,	24372·9
4101·45	1	4101·37 ,,	,,	,,	24374·8
4100·92	1	4100·82 ,,	,,	,,	24378·0
4100·37	1n	4100·26 ,,	,,	,,	24381·2
4098·37	2	4098·26 ,,	,,	6·9	24393·0
4096·85	2n	4096·67 ,,	,,	,,	24402·1
4096·16	2	4096·06 ,,	,,	,,	24406·2
4092·5	1n	4092·43 ,,	1·12	,,	24428
4091·76	1	4091·66 ,,	,,	,,	24432·5
4091·2	1n	4091·12 ,,	,,	,,	24436
4090·2	1n	4090·17 ,,	,,	,,	24442
4089·40	1	4089·28 ,,	,,	,,	24446·6
4088·73	1	4088·65 ,,	,,	,,	24450·6
4088·15	1n	4087·95 ,,	,,	,,	24454·0
4087·26	1	4087·16 ,,	,,	,,	24459·4
4085·50	3	4085·38 ,,	,,	,,	24469·9
4085·16	3	4085·07 ,,	,,	,,	24471·9
4084·60	3	4084·59 ,,	,,	,,	24475·3
4083·96	1n	4083·90 ,,	,,	,,	24479·1
4083·72	1n	4083·70 ,,	,,	,,	24480·6
4082·60	1n	4082·55 ,,	,,	,,	24487·3
4082·28	1n	4082·20 ,,	,,	,,	24489·2
4081·47	1	{4081·67 4081·35} ,,	,,	,,	24494·1
4081·02	1	4080·96 ,,	,,	,,	24496·8
4080·40	1	4080·30 ,,	,,	,,	24500·5
4080·02	2	4079·91 ,,	,,	,,	24502·8
4078·52	2	4078·41 ,,	,,	,,	24511·8
4077·85	1	4077·74 ,,	,,	,,	24515·8
4076·81	3	4076·72 ,,	,,	,,	24522·1

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
4074·97	3	4074·87 K. & R.	1·12	6·9	24533·2
4073·97	2	4073·84 ,, ·915 R.	,,	,,	24539·2
4071·92	10	4071·79 ,,	,,	,,	24551·5
4070·96	2	4070·85 ,,	,,	,,	24557·3
4068·15	3	4068·07 ,,	,,	,,	24574·3
4067·77	1		,,	,,	24576·6
4067·45	2	4067·36 ,,	,,	,,	24578·5
4067·12	3	4067·04 ,,	,,	,,	24580·5
4066·77	1	4066·66 ,,	,,	,,	24582·6
4065·57	1	4065·48 ,,	,,	,,	24589·9
4064·61	1	4064·55 ,,	,,	,,	24595·7
4064·35	1	4064·55 ,,	,,	,,	24597·3
4063·75	10	4063·63 ,,	,,	,,	24600·9
(4062·60)	3	4062·51 ,,	,,	,,	24607·9
4062·13	1n	4062·00 ,,	,,	,,	24610·7
4061·3	1b	4061·24 ,,	,,	,,	24616
4059·89	1	4059·80 ,,	,,	,,	24624·3
4059·75	1		,,	,,	24625·2
4058·93	1	{4058·99 4058·86} ,,	,,	,,	24630·1
4058·40	1	4058·30 ,,	,,	,,	24633·4
4057·55	1	4057·43 ,,	,,	,,	24638·5
4055·58	1	4055·63 ,,	,,	,,	24650·5
4055·12	1n	4055·12 ,,	,,	,,	24653·3
4054·95	1n	4054·94 ,,	1·11	,,	24654·3
4054·00	1n	4054·25 ,,	,,	,,	24660·1
4053·37	1n	4053·31 ,,	,,	,,	24663·9
4052·8	1n	4052·75 ,,	,,	,,	24667·0
4052·6	1n	4052·56 ,,	,,	,,	24669·0
4052·12	1n	4052·03 ,,	,,	,,	24671·5
4051·52	1n	4051·40 ,,	,,	,,	24674·8
4050·86	1n	4050·83 ,,	,,	7·0	24679·1
4050·02	2	4049·92 ,,	,,	,,	24684·2
4049·50	1	4049·40 ,,	,,	,,	24687·4
4049·03	1n	4048·82 ,, ·875 R.	,,	,,	24690·3
4047·46	1	4047·40 ,,	,,	,,	24699·9
4045·98	10	4045·90 ,,	,,	,,	24708·9
4044·79	2	4044·69 ,,	,,	,,	24716·2
4044·08	2	4044·00 ,,	,,	,,	24720·5
4042·00	2	4041·44 ,,	,,	,,	24733·2
4040·86	2	4040·74 ,,	,,	,,	24740·2
4038·95	1n	4038·83 ,,	,,	,,	24751·9
4034·65	1	4034·59 ,,	,,	,,	24778·3
4033·82	1		,,	,,	24783·4
4033·24	1	4033·16 ,,	,,	,,	24787·0
4032·80	2	4032·72 ,,	,,	,,	24789·7
4032·14	2	4032·06 ,,	,,	,,	24793·7
4030·89	2n	4030·84 ,,	,,	,,	24801·4
4030·69	2	4030·60 ,,	,,	,,	24802·6
4030·37	1	4030·26 ,,	,,	,,	24804·6
4029·80	2	4029·72 ,,	,,	,,	24808·1
4025·99	1	4025·93 ,,	,,	,,	24831·6
4024·94	2	4024·86 ,,	,,	,,	24838·1
4024·26	1	4024·20 ,,	,,	,,	24842·3
4022·05	3	4022·25 ,,	,,	,,	24855·9

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4018·42	1	4018·36 K. & R.	1·11	7·0	24878·4
4017·29	3	4017·23 ,,	,,	,,	24885·4
4016·57	1	4016·55 ,,	,,	,,	24889·9
4014·70	4	4014·63 ,,	1·10	,,	24901·5
4013·96	1	4013·91 ,,	,,	,,	24906·1
4011·50	1	4011·49 ,,	,,	,,	24921·9
(4009·86)	3	4009·80 ,,	,,	,,	24931·5
4009·37	1		,,	,,	24934·6
4008·95	1n	4008·97 ,,	,,	,,	24937·2
4007·41	2	4007·36 ,,	,,	,,	24946·8
4006·79	1	4006 71 ,,	,,	,,	24950·6
4006·47	1	4006·39 ,,	,,	,,	24952·6
4005·94	1		,,	,,	24955·9
4005·40	8	4005·33 ,,	,,	,,	24959·3
4005·05	1n	4005·07 ,,	,,	,,	24961·5
4003·91	1	4003·88 ,,	,,	,,	24968·6
4002·75	1	4002·77 ,,	,,	7·1	24975·7
4002·20	1		,,	,,	24979·2
4001·80	2	4001 77 ,,	,,	,,	24981·7
4001·49	1		,,	,,	24983·6
4001·37	1		,,	,,	24984·3
4000·60	1	4000·57 ,,	,,	,,	24989·2
4000·35	1	4000·36 ,,	,,	,,	24990·7
3998·16	3	3998·16 ,,	,,	,,	25004·4
3997·52	4	3997·49 ,,	,,	,,	25008·4
3997·10	1	3997·06 ,,	,,	,,	25011·0
3996·11	1	3996·08 ,,	,,	,,	25017·2
3994·22	1	3994·22 ,,	,,	,,	25029·0
3990·50	1	3990·48 ,,	,,	,,	25052·4
3990·00	1	3989·94 ,,	,,	,,	25055·6
3986·29	1	3986·27 ,,	,,	,,	25078·9
3985·48	1	3985·46 ,,	,,	,,	25084·0
3984·09	3	*3984·08 ,, ·067 R.	,,	,,	25092·7
3982·35	1b		,,	,,	25103·7
3981·90	2	3981·87 ,,	,,	,,	25106·5
3977·89	4	3977·83 ,,	,,	,,	25131·9
3976·97	1	3976·95 ,,	,,	,,	25137·7
3976·72	1	3976·71 ,,	,,	,,	25139·3
3973·75	2n	3973·75 ,,	1·09	,,	25158·0
3972·55	1n		,,	,,	25165·6
3971·47	2	3971·41 ,,	,,	,,	25172·5
3970·51	1	3970·51 ,,	,,	,,	25178·6
3969·40	8	3969·34 ,,	,,	,,	25185·6
3968·58	8 C	3968·55 ,,	,,	,,	25190·8
3968·10	1	3968·05 ,,	,,	,,	25193·9
3967·58	3	3967·51 ,,	,,	,,	25197·2
3966·75	3	3966·70 ,,	,,	,,	25202·5
3966·20	3	3966·16 ,,	,,	,,	25206·0
3964·66	1	3964·61 ,,	,,	,,	25215·7
3963·25	1	3963·24 ,,	,,	,,	25224·7
3961·30	1n	3961·24 ,,	,,	,,	25237·1
3960·40	1n	3960·38 ,,	,,	,,	25242·9
3957·15	1n	3957·17 ,,	,,	,,	25263·6
3956·82	4	3956·77 ,,	,,	,,	25265·7
3956·58	3	3956·54 ,,	,,	,,	25267·3

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3955·50	1n	3955·50 K. & R.	1·09	7·2	25274·1
3953·25	1	3953·25 ,,	,,	,,	25288·4
3952·74	2	3952·71 ,,	,,	,,	25291·7
3951·30	3	3951·25 ,,	,,	,,	25300·9
(3950·10)	3	3950·05 ,,	,,	,,	25308·6
3948·88	4	3948·87 ,,	,,	,,	25316·4
3948·31	3	3948·23 ,,	,,	,,	25320·1
3947·64	2	3947·64 ,,	,,	,,	25324·4
3947·10	1	3947·11 ,,	,,	,,	25327·9
3945·22	1n	3945·22 ,,	,,	,,	25339·9
3945·00	1n	3945·00 ,,	,,	,,	25341·3
3943·45	1	3943·43 ,,	,,	,,	25351·3
3942·55	2	*3942·54 ,, ·555 R.	,,	,,	25357·1
3941·40	1n	3941·40 ,,	,,	,,	25364·5
3940·99	2	3940·98 ,,	,,	,,	25367·1
3939·06	1n		,,	,,	25379·6
3937·67	1		,,	,,	25388·5
3937·42	1	3937·42 ,,	,,	,,	25390·1
3935·90	2	3935·92 ,,	1·08	,,	25399·9
3935·41	1	3935·40 ,,	,,	,,	25403·1
3934·18	1		,,	,,	25411·1
3933·80	8 Ca	3933·75 ,,	,,	,,	25413·5
3933·05	1	3933·01 ,,	,,	,,	25418·4
3932·75	2	3932·71 ,,	,,	,,	25420·3
3931·96	1		,,	,,	25425·4
3931·22	1	3931·22 ,,	,,	,,	25430·2
3930·43	6	3930·37 ,,	,,	,,	25435·3
3929·82	1		,,	,,	25439·3
3929·26	1	3929·24 ,,	,,	,,	25442·9
3928·09	7	3928·17 ,,	,,	,,	25450·5
3926·06	2	3926·05 ,,	,,	,,	25463·6
3925·76	1	3925·74 ,,	,,	,,	25465·6
3925·33	1n	3925·31 ,,	,,	,,	25468·4
3923·05	6	3923·00 ,,	,,	,,	25483·2
3920·40	5	3920·36 ,,	,,	,,	25500·4
3919·17	2	3919·18 ,,	,,	,,	25508·4
3918·75	3	3918·74 ,,	,,	,,	25511·1
3918·47	3n	3918·49 ,,	,,	,,	25513·0
3917·28	3	3917·29 ,,	,,	,,	25520·7
3916·84	3	3916·82 ,, ·880 R	,,	,,	25523·6
3914·39	1	3914·35 ,,	,,	,,	25539·6
3913·74	1	3913·74 ,,	,,	,,	25543·8
3910·95	1	3910·95 ,,	,,	,,	25562·0
3909·95	1n	3909·95 ,,	,,	,,	25568·6
3908·06	1	3908·02 ,,	,,	7·3	25580·8
3907·60	1	3907·58 ,,	,,	,,	25583·9
3906·87	1n	3906·84 ,,	,,	,,	25588·6
3906·59	5	3906·58 ,,	,,	,,	25590·5
3906·2	1n		,,	,,	25593·0
3904·00	2	3904·00 ,,	,,	,,	25607·5
3903·65	1		,,	,,	25609·7
3903·09	7	3903·06 ,,	,,	,,	25613·4
3900·63	1	3900·64 ,,	,,	,,	25529·6

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3899·84	6	3899·80 K. & R.	1·08	7·3	25634·8
3899·12	1	3899·13 ,,	,,	,,	25639·5
3898·05	4	3898·05 ,,	,,	,,	25646·6
3897·58	1	3897·54 ,, ·605 R.	,,	,,	25649·6
3895·78	5	3895·75 ,,	1·07	,,	25661·5
3894·10	1	3894·09 ,,	,,	,,	25672·6
3893·50	3	3893·47 ,,	,,	,,	25676·5
3892·05	2	3892·02 ,,	,,	,,	25686·1
3890·96	1	3890·94 ,,	,,	,,	25693·3
3888·95	2n	3888·92 ,,	,,	,,	25706·6
3888·65	6	3888·63 ,,	,,	,,	25708·6
3887·18	5	3887·17 ,,	,,	,,	25718·3
3886·41	8	3886·38 ,,	,,	,,	25723·4
3885·63	3	3885·61 ,,	,,	,,	25728·6
3885·30	1	3885·25 ,,	,,	,,	25730·7
3884·49	2	3884·46 ,,	,	,,	25736·1
3883·44	2	3883·39 ,,	,,	,,	25743·1
3278·71	8	3878·82 ,,	,,	,,	25775·5
3878·15	7	3878·12 ,,	,,	,,	25778·2
3876·15	1	3876·14 ,,	,,	,,	25791·5
3873·89	4	3873·88 ,,	,,	,,	25806·5
3872·65	6	3872·61 ,,	,,	,,	25814·8
3871·88	3	3871·86 ,,	,,	,,	25820·0
3869·69	2	3869·69 ,,	,,	,,	25834·6
3868·03	1	3868·03 ,,	,,	,,	25845·6
3867·33	3	3867·33 ,,	,,	,,	25850·3
3865·67	6	3865·65 ,,	,,	,,	25861·4
3863·86	1	3863·87 ,,	,,	,,	25873·6
3861·46	1	3861·46 ,,	,,	,,	25889·6
3860·07	9	3860·03 ,,	,,	,,	25899·0
3859·36	4	3859·34 ,,	,,	,,	25903·7
3857·03	1		,,	,,	25919·4
3856·51	8	3856·49 ,,	1·06	,,	25922·9
3855·45	1n	3855·45 ,,	,,	,,	25930·0
3854·52	1n	3854·51 ,,	,,	,,	25936·3
3853·6	1b	3853·60 ,,	,,	,,	25943
3852·71	2	3852·71 ,,	,,	,,	25948·5
3850·99	3	3850·96 ,,	,,	,,	25960·0
3850·69	1		,,	,,	25962·1
3850·15	6	3850·11 ,,	,,	,,	25965·7
3848·47	1	3848·42 ,,	,,	,,	25977·1
3846·91	3	3846·96 ,,	,,	,,	25987·6
3846·54	2	3846·55 ,,	,,	,,	25990·1
3846·18	1	3846·18 ,,	,,	,,	25992·5
3845·82	1	3845·84 ,,	,,	,,	25995·0
3845·30	1	3845·30 ,,	,,	,,	25998·5
3844·45	1n		,,	,,	26004·3
3843·41	4	3843·40 ,,	,,	,,	26011·3
3841·21	8	3841·19 ,,	,,	,,	26026·2
3840·61	8	3840·58 ,,	,,	,,	26030·2
3839·87	2	3839·78 ,,	,,	,,	26035·3
3839·40	4	3839·38 ,,	,,	,,	26038·4
3838·2	1b		,,	,,	26047
3837·25	1	3837·27 ,,	,,	,,	26053·0
3836·44	2	3836·48 ,,	,,	,,	26058·5

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3834·82	1		1·06	7·3	26069·5
3834·38	8	3834·37 K. & R.	,,	,,	26072·5
3833·44	3	3833·44 ,,	,,	,,	26078·9
3832·4	1b		,,	,,	26086
3831·77	1		,,	,,	26090·3
3830·96	1	3830·95 ,,	,,	,,	26095·8
3830·53	1n	3830·54 ,,	,,	,,	26098·8
3829·85	1	3829·86 ,,	,,	,,	26103·4
3829·56	1	3829·59 ,,	,,	,,	26105·4
3829·25	1	3829·30 ,,	,,	,,	26107·5
3827·98	9	3827·96 ,,	,,	,,	26116·1
3826·96	1	3826·99 ,,	,,	,,	26123·1
3826·04	9	3826·04 ,,	,,	,,	26129·4
3825·10	1		,,	,,	26135·8
3824·58	7	3824·58 ,,	,,	,,	26139·4
3821·96	2	3821·98 ,,	,,	,,	26157·3
3821·30	4	3821·32 ,,	,,	,,	26161·8
3820·57	9	3820·56 ,,	,,	,,	26166·8
3819·80	1n	3819·75 ,,	,,	,,	26172·1
3817·77	1n	3817·84 ,,	,,	7·4	26185·9
3816·46	1	3816·48 ,,	1·05	,,	26194·9
3815·99	9	3815·97 ,,	,,	,,	26198·1
3814·90	1	3814·94 ,,	,,	,,	26205·6
3814·65	2	3814·66 ,,	,,	,,	26207·3
3814·01	1	3814·03 ,,	,,	,,	26211·7
3813·77	1	3813·77 ,,	,,	,,	26213·4
3813·12	5	3813·12 ,,	,,	,,	26217·8
3812·04	1n	3812·03 ,,	,,	,,	26225·3
3810·87	1	3810·89 ,,	,,	,,	26233·3
3809·70	1	3809·70 ,,	,,	,,	26241·4
3808·85	1	3808·86 ,,	,,	,,	26247·2
3807·65	2	3807·68 ,,	,,	,,	26255·5
3806·81	4	3806·84 ,,	,,	,,	26261·3
3806·34	1	3806·36 ,,	,,	,,	26264·6
3805·48	5	3805·47 ,,	,,	,,	26270·5
3804·15	1	3804·15 ,,	,,	,,	26279·7
3802·40	1	3802·41 ,,	,,	,,	26291·8
3801·87	1n		,,	,,	26295·4
3801·80	1	3801·81 ,,	,,	,,	26295·9
3799·70	7	3799·68 ,,	,,	,,	26310·5
3798·68	6	3798·65 ,,	,,	,,	26317·5
3797·64	4	3797·65 ,,	,,	,,	26324·7
3795·15	6	3795·13 ,,	,,	,,	26342·0
3794·48	2	3794·46 ,,	,,	,,	26346·7
3794·00	1	3793·99 ,,	,,	,,	26350·0
3793·60	1n	3793·60 ,,	,,	,,	26352·8
3792·29	1	3792·28 ,,	,,	,,	26361·9
3790·92	1	3790·88 ,,	,,	,,	26371·4
3790·23	3	3790·22 ,,	,,	,,	26376·2
3789·31	1	3789·31 ,,	,,	,,	26382·6
3788·02	5	3788·01 ,,	,,	,,	26391·6
3787·30	1	3787·30 ,,	,,	,,	26396·6
3786·82	2	3786·81 ,,	,,	,,	26400·0
3786·30	2	3786·30 ,,	,,	,,	26403·6
3786·06	3	3786·07 ,,	,,	,,	26405·3

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
3782·07	1n	3782·05 K. & R.	1·05	7·4	26433·2
3781·31	1	3781·31 ,,	,,	,,	26438·5
3779·59	1	3779·58 ,,	,,	,,	26450·5
3778·64	1	3778·63 ,,	,,	,,	26457·2
3777·56	1	3777·56 ,,	,,	,,	26464·7
3777·22	1	3777·20 ,,	,,	,,	26467·1
3776·67	1	3776·58 ,,	1·04	,,	26471·0
3774·95	1	3774·95 ,,	,,	,,	26483·0
3773·83	1	3773·84 ,,	,,	,,	26490·9
3771·10	1n		,,	7·5	26510·0
3770·44	1	3770·43 ,,	,,	,,	26514·6
3770·13	1	3770·12 ,,	,,	,,	26516·8
3768·14	1	3768·15 ,,	,,	,,	26530·8
3767·32	7	3767·31 ,,	,,	,,	26536·6
3766·78	1	3766·74 ,,	,,	,,	26540·4
3766·20	1	3766·19 ,,	,,	,,	26544·5
3765·70	5	3765·66 ,,	,,	,,	26548·0
3763·91	7	3763·90 ,,	,,	,,	26560·6
3763·1	1b		,,	,,	26566
3762·2	1b	3762·30 ,,	,,	,,	26573
3761·50	1n	3761·52 ,,	,,	,,	26577·6
3760·68	2	3760·66 ,,	,,	,,	26583·4
3760·19	3	3760·17 ,,	,,	,,	26586·9
3759·62	1b		,,	,,	26590·9
3759·35	1b	3759·30 ,,	,,	,,	26592·8
3758·92	1		,,	,,	26595·9
3758·39	8	3758·36 ,,	,,	,,	26599·6
3757·60	1	3757·60 ,,	,,	,,	26605·2
3757·08	2	3757·06 ,,	,,	,,	26608·9
(3756·21)	1	3756·17 ,,	,,	,,	26615·1
3754·62	1n	*3754·63 ,, ·652 R.	,,	,,	26626·4
3753·74	3	3753·74 ,,	,,	,,	26632·6
3753·4	1n		,,	,,	26635
3752·56	1	3752·57 ,,	,,	,,	26641·0
3752·2	1b		,,	,,	26644
3749·64	10	3749·61 ,,	,,	,,	26661·7
3749·05	2	3749·06 ,,	,,	,,	26665·9
3748·41	7	3748·39 ,,	,,	,,	26670·5
3747·02	2	*3747·09 ,, ·094 R.	,,	,,	26680·4
3746·55	1	3746·56 ,,	,,	,,	26683·7
3746·04	7	3745·95 ,,	,,	,,	26687·4
3745·71	7	3745·67 ,,	,,	,,	26689·7
3744·70	1		,,	,,	26696·9
3744·60	1		,,	,,	26697·6
3744·20	1	3744·21 ,,	,,	,,	26700·5
3743·51	7	{3743·58 ,, 3743·45 ,,	,,	,,	26705·4
3742·73	1	3742·77 ,,	,,	,,	26711·0
3741·95	1n		,,	,,	26716·5
3740·9	1n		,,	,,	26724
3740·39	1	3740·44 ,,	,,	,,	26727·7
3740·18	1	3740·22 ,,	,,	,,	26729·2
3739·65	1	3739·73 ,,	,,	,,	26733·0
3738·40	3	3738·44 ,,	,,	,,	26741·9
3737·27	8	3737·27 ,,	1·03	,,	26750·0

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
3735·44	3	3735·45 K. & R.	1·03	7·5	26763·1
3735·01	10	3735·00 ,,	,,	,,	26766·2
3733·46	6	3733·46 ,,	,,	,,	26777·3
3732·50	4	3732·54 ,,	,,	,,	26784·2
3731·50	1	3731·51 ,,	,,	,,	26791·4
3731·05	1	3731·07 ,,	,,	,,	26794·6
3730·51	2	3730·53 ,,	,,	,,	26798·5
3728·78	1	3728·81 ,,	,,	,,	26810·9
3727·78	7	3727·78 ,,	,,	7·6	26818·0
3727·23	2	3727·13 ,,	,,	,,	26822·0
3727·02	2		,,	,,	26823·5
3725·60	1	3725·62 ,,	,,	,,	26833·7
3724·49	3	3724·51 ,,	,,	,,	26841·7
3722·73	6	3722·69 ,,	,,	,,	26854·4
3722·06	1	3722·07 ,,	,,	,,	26859·2
3721·68	1n	3721·69 ,,	,,	,,	26862·0
3721·35	1	3721·41 ,,	,,	,,	26864·4
3720·10	8	3720 07 ,,	,,	,,	26873·4
3718·53	1	3718·55 ,,	,,	,,	26884·7
3716·54	3	3716·59 ,,	,,	,,	26899·2
3716·01	1	3716 04 ,,	,,	,,	26903·0
3711·52	1	3711·54 ,,	,,	,,	26935·5
3711·33	1	3711·35 ,,	,,	,,	26936·9
3709·40	6	3709·37 ,,	,,	,,	26950·9
3708·06	5	3708·03 ,,	,,	,,	26960·7
3708·01	2		,,	,,	26961·0
3707·65	1n	3707·60 ,,	,,	,,	26963·7
3707·16	2	3707·18 ,,	,,	,,	26967·2
3705·73	6	3705·70 ,,	,,	,,	26977·6
3704·59	3	3704·59 ,,	,,	,,	26985·9
3703·95	1	3703·96 ,,	,,	,,	26990·6
3703·81	1	3703·83 ,,	,,	,,	26991·6
3703·67	1	3703·68 ,,	,,	,,	26992·6
3702·60	1	3702·63 ,,	,,	,,	27000·5
3702·17	1	3702·16 ,,	,,	,,	27003·6
3701·20	4	3701·20 ,,	,,	,,	27010·7
3698·75	1	3698·73 ,,	,,	,,	27028·6
3697·58	2	3697·58 ,,	1·02	,,	27037·1
(3695·20)	3	3695·18 ,,	,,	,,	27054·5
3694·13	4	3694·13 ,,	,,	,,	27062·4
3693·20	1	3693·16 ,,	,,	,,	27069·2
3690 87	2	3690·86 ,,	,,	,,	27086·3
3690·60	1	3690·60 ,,	,,	,,	27088·3
3689·57	3	3689·58 ,,	,,	,,	27095·8
3688·64	1n	3688·65 ,,	,,	,,	27102·7
3687·70	3	3687·77 ,,	,,	,,	27109·6
3687·55	6	3687·58 ,,	,,	,,	27110·7
3687·24	1	3687·21 ,,	,,	,,	27113·0
3686·38	1	3686·40 ,,	,,	,,	27119·3
3686·13	3	3686·10 ,,	,,	,,	27121·1
3684·25	4	3684·24 ,,	,,	,,	27135·0
3683·19	3	3683·18 ,,	,,	7·7	27142·7
3682·35	4	3682·35 ,,	,,	,,	27148·9
3680·88	1b	3680·90 ,,	,,	,,	27159 7
3680·06	5	3680·03 ,,	,,	,,	27165·8

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3678·97	1	3678·99 K. & R.	1·02	7·7	27173·8
3677·71	4	3677·76 ,,	,,	,,	27183·1
3677·42	2	3677·42 ,,	,,	,,	27185·3
3676·42	2	3676·44 ,,	,,	,,	27192·7
3674·88	1	3674·89 ,,	,,	,,	27204·1
3674·6	1n	3674·55 ,,	,,	,,	27206
3670·92	1	3670·95 ,,	,,	,,	27233·4
3670·19	2	3670·20 ,,	,,	,,	27238·8
3669·63	3	3669·65 ,,	,,	,,	27243·0
3669·26	1	3669·29 ,,	,,	,,	27245·8
3668·11	1n	3668·11 ,,	,,	,,	27254·3
3667·38	1	3667·45 ,,	,,	,,	27259·7
3666·38	1n	3666·41 ,,	,,	,,	27267·2
3664·71	1n	3664·74 ,,	,,	,,	27279·6
3663·56	1n	3663·60 ,,	,,	,,	27288·2
3662·98	1n	3663·04 ,,	,,	,,	27292·5
3659·63	2	3659·65 ,,	,,	,,	27317·5
3658·07	1n	3658·07 ,,	,,	,,	27329·1
3657·25	1	3657·27 ,,	1·01	,,	27335·3
3656·33	1	3656·37 ,,	,,	,,	27342·1
3655·70	1n		,,	,,	27346·8
3655·57	1	3655·60 ,,	,,	,,	27347·8
3653·71	1	3653·90 ,,	,,	,,	27361·7
3651·60	4	3651·61 ,,	,,	,,	27377·6
3650·40	2	3650·42 ,,	,,	,,	27386·6
3650·13	1	3650·14 ,,	,,	,,	27388·6
3649·62	4	3649·65 ,,	,,	,,	27392·4
3649·41	1	3649·44 ,,	,,	,,	27394·0
(3648·00)	9	3647·99 ,,	,,	,,	27404·6
3647·56	1	3647·57 ,,	,,	,,	27407·9
3645·93	2	3645·96 ,,	,,	,,	27420·1
3645·65	1	3645·63 ,,	,,	,,	27422·3
3645·20	1	3645·22 ,,	,,	,,	27425·6
3643·80	1n	3643·80 ,,	,,	,,	27436·2
3640·53	5	3640·53 ,,	,,	,,	27460·8
3638·42	4	3638·44 ,,	,,	7·8	27476·7
3637·98	1	3637·98 ,,	,,	,,	27480·0
3637·40	1	3637·39 ,,	,,	,,	27484·4
3637·11	1	3637·16 ,,	,,	,,	27486·6
3636·77	1	3636·73 ,,	,,	,,	27489·1
3636·32	1	3636·32 ,,	,,	,,	27492·5
3635·3	1n	3635·39 ,,	,,	,,	27500
3634·8	1b	3634·80 ,,	,,	,,	27504
3634·45	1n	3634·48 ,,	,,	,,	27506·7
3633·97	1n	3633·98 ,,	,,	,,	27510·3
3633·12	1	3633·16 ,,	,,	,,	27516·8
3632·65	1	3632·71 ,,	,,	,,	27520·3
3632·15	2	3632·20 ,,	,,	,,	27524·0
3631·64	10	3631·62 ,,	,,	,,	27528·0
3631·23	2	3631·23 ,,	,,	,,	27531·1
3630·50	1	3630·50 ,,	,,	,,	27536·6
3628·0	1n	3627·91 ,,	,,	,,	27556
3625·27	1	3625·30 ,,	,,	,,	27576·4
3625·00	1n	3624·95 ,,	,,	,,	27578·4
3624·5	1n	3624·46 ,,	,,	,,	27582

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3623·92	1	3623·94 K. & R.	1·01	7·8	27586·6
3623·58	1	3623·58 ,,	,,	,,	27589·2
3623·31	2	3623·33 ,,	,,	,,	27591·3
3622·15	3	3622·15 ,,	,,	,,	27600·1
3621·7	1b	3621·87 ,,	,,	,,	27604
3621·60	4	3621·61 ,,	,,	,,	27604·3
3620·65	1n	3620·62 ,,	,,	,,	27611·6
3619·7	1n	{ 3619·89 3619·54 ,,		,,	27619
3618·92	10	3618·92 ,,	,,	,,	27624·8
3618·50	2	3618·54 ,,	,,	,,	27628·0
3617·90	4	3617·94 ,,	1·00	,,	27632·5
3617·44	1	3617·47 ,,	,,	,,	27636·1
3616·68	1	{ 3616·76 3616·46 ,,	,,	,,	27641·9
3615·30	1n	3615·41 ,,	,,	,,	27652·4
3614·8	1b	3614·78 ,,	,,	,,	27656
3614·27	1n	3614·26 ,,	,,	,,	27660·3
3613·6	1n	{ 3613·75 } 3613·58 } ,,	,,	,,	27665
3613·3	1n	3613·26 ,,	,,	,,	27668
3613·1	1n	3613·10 ,,	,,	,,	27669
3612·6	1n		,,	,,	27673
3612·24	1	3612·25 ,,	,,	,,	27675·9
3610·82	1	3610·86 ,,	,,	,,	27686·7
3610·30	4	3610·29 ,,	,,	,,	27690·7
3609·51	1		,,	,,	27696·8
3609·02	9	3608·99 ,,	,,	,,	27700·6
3607·30	1		,,	,,	27713·8
3606·85	6	3606·83 ,,	,,	,,	27717·2
3605·60	5	3605·62 ,,	,,	,,	27726·8
3605·40	1n		,,	,,	27728·4
3603·96	1	3603·98 ,,	,,	,,	27739·5
3603·35	3	3603·34 ,,	,,	,,	27744·2
3602·64	1	3602·64 ,,	,,	,,	27749·6
3599·77	1	3599·77 ,,	,,	,,	27771·8
3599·30	1	3599·30 ,,	,,	,,	27775·4
3597·20	1n	3597·22 ,,	,,	,,	27791·6
3596·3	1n	3596·35 ,,	,,	,,	27799
3595·4	1n	3595·43 ,,	,,	,,	27806
3594·78	2	3594·71 ,,	,,	7·9	27810·2
3589·58	1	3589·58 ,,	,,	,,	27850·5
3589·24	1	3589·25 ,,	,,	,,	27853·1
3589·05	1	3589·05 ,,	,,	,,	27854·6
3588·75	1	3588·75 ,,	,,	,,	27857·0
3587·87	1	3587·87 ,,	,,	,,	27863·8
3587·56	1	3587·55 ,,	,,	,,	27866·1
3587·10	5	3587·10 ,,	,,	,,	27869·8
3586·25	4	3586·24 ,,	,,	,,	27876·4
3585·85	4	3585·84 ,,	,,	,,	27879·5
3585·49	5	3585·43 ,,	,,	,,	27882·3
3585·10	3	3585·08 ,,	,,	,,	27885·3
3584·81	4	3584·78 ,,	,,	,,	27887·6
3583·48	1	3583·45 ,,	,,	,,	27897·9
3582·35	2	3582·32 ,,	,,	,,	27906·7

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
3581·36	10r	3581·32 K. & R.	1·00	7.9	27914·5
3578·78	1	3578·80 ,,	,,	,,	27934·6
3578·53	1	3578·49 ,,	,,	,,	27936·5
3577·8	1n		0·99	,,	27942
3576·90	1	3576·89 ,,	,,	,,	27949·3
3576·17	1n	3576·11 ,,	,,	,,	27955·0
3575·52	1	3575·49 ,,	,,	,,	27960·1
3574·04	2	3574·00 ,,	,,	,,	27971·6
3573·55	1	3573·52 ,,	,,	,,	27975·5
3572·75	1n	3572·79 ,,	,,	,,	27981·7
3572·13	2	3572·12 ,,	,,	,,	27986·6
3571·38	1	3571·34 ,,	,,	,,	27992·5
3570·42	8	3570·45 ,,	,,	,,	28000·0
3570·18	8	3570·23 ,,	,,	,,	28001·9
3569·12	1	3569·09 ,,	,,	,,	28010·2
3569·00	1	3568·94 ,,	,,	,,	28011·2
3568·55	1	3568·53 ,,	,,	,,	28014·7
3567·20	1	3567·15 ,,	,,	,,	28025·3
3566·75	1n	3566·70 ,,	,,	,,	28028·8
3566·25	1n	3566·46 ,,	,,	,,	28032·8
3565·54	8r	3565·50 ,,	,,	,,	28038·4
3564·67	1	3564·61 ,,	,,	,,	28045·2
3562·0	1b		,,	,,	28066
3560·83	1	3560·81 ,,	,,	,,	28075·4
3559·65	1	3559·62 ,,	,,	,,	28084·8
3558·68	6	3558·62 ,,	,,	,,	28092·4
3557·02	3	3556·99 ,,	,,	,,	28105·5
3555·09	5	3555·04 ,,	,,	,,	28120·8
3554·7	1n	3554·62 ,,	,,	,,	28124
3554·32	1	3554·24 ,,	,,	,,	28126·9
3553·91	2	3553·84 ,,	,,	,,	28130·1
3553·01	1	3552·95 ,,	,,	,,	28137·3
3552·28	1	3552·24 ,,	,,	,,	28143·0
3549·98	1	3549·97 ,, ·011 R.	,,	8·0	28161·2
3548·17	1	3548·13 ,,	,,	,,	28175·5
3547·33	1	3547·31 ,,	,,	,,	28182·2
3545·76	2	3545·74 ,,	,,	,,	28194·7
3544·75	1	3544·74 ,,	,,	,,	28202·7
3543·82	1	3543·78 ,,	,,	,,	28210·1
3543·60	1n	3543·53 ,,	,,	,,	28211·9
3542·21	5	3542·20 ,,	,,	,,	28223·0
3541·23	4	3541·22 ,,	,,	,,	28230·8
3540·90	1n	3548·82 ,,	,,	,,	28233·4
(3540 27)	1	3540·24 ,, ·266 R.	,,	,,	28238·4
3538·06	1	3538·01 ,,	,,	,,	28256·1
3537·88	1	3537·84 ,,	0·98	,,	28257·5
3537·68	1	3537·60 ,,	,,	,,	28259·1
3536·59	4	3536·65 ,,	,,	,,	28267·8
3533·36	3	3533·30 ,,	,,	,,	28293·7
3533·12	2	3533·08 ,,	,,	,,	28295·6
3530·55	1	3530·48 ,,	,,	,,	28316·2
3529·97	2	3529·90 ,,	,,	,,	28320·9
3527·94	2	3527·90 ,,	,,	,,	28337·2
3526·83	2	3526·76 ,,	,,	,,	28346·1
3526·60	3	3526·51 ,,	,,	,,	28347·9

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3526·31	4	3526·25 K. & R.	0·98	8·0	28350·3
3526·15	4	3526·08 ,,	,,	,,	28351·5
3524·38	2	3524·34 ,,	,,	,,	28365·7
3524·22	1	3524·15 ,,	,,	,,	28367·1
3523·47	1	3523·38 ,,	,,	,,	28373·1
3522·43	1	3522·37 ,,	,,	,,	28381·5
3521·99	1	3521·93 ,,	,,	,,	28385·0
3521·41	6	3521·36 ,,	,,	,,	28389·7
3519·00	1n	3518·96 ,,	,,	,,	28409·2
3516·53	1	3516·50 ,,	,,	,,	28429·1
3513·96	5	3513·91 ,,	,,	,,	28449·9
3513·17	1n	3513·15 ,,	,,	,,	28456·3
3510·55	1	3510·52 ,,	,,	8·1	28477·5
3510·0	1n	3509·95 ,,	,,	,,	28482
3508·63	1	3508·58 ,,	,,	,,	28493 1
3506·64	1	3506·59 ,,	,,	,,	28509·2
3505·20	1	3505·39 3505·15 ,,	,,	,,	28520 9
3504·99	1	3504·95 ,,	,,	,,	28522·7
3500·71	1	3400·64 ,,	,,	,,	28557·5
3498·00	5	3497·92 ,,	0·97	,,	28579·7
3497·26	3	3497·20 ,,	,,	,,	28585·7
3495·44	2	3495·37 ,,	,,	,,	28600·6
3494·9	1n	3494·76 ,,	,,	,,	28605
3493·63	2	3493·78 ,,	,,	,,	28615·4
3490·73	6	3490·65 ,,	,,	,,	28639·2
3489·82	1	3489·74 ,,	,,	,,	28646·7
3485·49	2	3485·42 ,,	,,	,,	28682·3
3483·15	1	3483·09 ,,	,,	,,	28701·5
3478·80	1n	3478·69 ,,	,,	,,	28737·4
3478·00	1n	3477·93 ,,	,,	,,	28744·1
3476·85	5	3476·75 ,,	,,	,,	28753·6
3475·61	7	3475·52 ,,	,,	,,	28763·8
3474·59	1	3474·51 ,,	,,	,,	28772·3
3471·46	2	3471·40 ,,	,,	,,	28798·2
3469·97	1	3469·91 ,,	,,	8·2	28810·5
3469·13	1n	3469·09 ,,	,,	,,	28817·5
3468·94	1	3468·92 ,,	,,	,,	28819·0
3468·80	1		,,	,,	28820·2
3466·01	7	3465·95 ,,	,,	,,	28843·4
3460·04	1	3460·02 ,,	,,	,,	28893·2
3458·44	1	3458·39 ,,	0·96	,,	28906·6
3457·05	1n	3457·15 ,,	,,	,,	28918·2
3453·13	1	3453·10 ,,	,,	,,	28951·0
3452·41	2	3452·35 ,,	,,	,,	28957·1
3452·16	2		,,	,,	28959·2
3451·80	1n	3451·99 ,,	,,	,,	28962·2
3450·47	2	3450·41 ,,	,,	,,	28973·4
3447·43	2	3447·37 ,,	,,	,,	28998·9
3445·30	4	3445·22 ,,	,,	,,	29016·9
(3444·03)	5	3443·96 ,,	,,	,,	29027·5
3442·82	1	3442·75 ,,	,,	,,	29037·8
3442·51	1	3442·44 ,,	,,	,,	29040·4
3441·16	6	3441·07 ,,	,,	,,	29051·8
3440·77	7	3440·69 ,,	,,	,,	29055·1

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3440·02	1	3439·93 K. & R.	0·96	8·2	29061·4
3438·42	1	3438·36 ,,	,,	,,	29074·9
3438·19	1	3438·02 ,,	,,	,,	29076·9
3436·25	1n	3436·06 ,,	,,	,,	29093·3
3433·72	1	3433·64 ,,	,,	,,	29114·7
3431·98	1	3431·90 ,,	,,	8·3	29129·4
3428·35	2	3428·26 ,,	,,	,,	29160·3
3427·29	5	3427·21 ,,	,,	,,	29169·3
3426·81	2	3426·71 ,,	,,	,,	29173·4
3426·53	2	3426·44 ,,	,,	,,	29175·7
3425·17	1	3425·08 ,,	,,	,,	29187·3
3424·45	3	3424·36 ,,	,,	,,	29193·5
3422·82	2		,,	,,	29207·4
3422·68	1	3422·69 ,,	,,	,,	29208·6
3418·66	3	3418·58 ,,	,,	,,	29242·9
3417·99	3	3417·92 ,,	0·95	,,	29248·7
3415·70	1	3415·61 ,,	,,	,,	29268·3
3413·31	5	3413·22 ,,	,,	,,	29288·8
3411·50	1	3411·43 ,,	,,	,,	29304·3
3410·30	1	3410·26 ,,	,,	,,	29314·6
3407·62	6	3407·55 ,,	,,	,,	29337·7
3406·96	2	3406·88 ,,	,,	,,	29343·4
3406·62	1n	3406·50 ,, ·566 R.	,,	,,	29346·3
3404·50	3	3404·41 ,,	,,	,,	29364·6
3402·42	2	3402·33 ,,	,,	,,	29382·5
3401·68	1	3401·60 ,,	,,	,,	29389·2
(3399·49)	5	3399·39 ,,	,,	,,	29407·9
3398·45	1n	3398·29 ,,	,,	,,	29416·9
3397·75	1n	3397·68 ,,	,,	,,	29422·9
3397·10	1	3397·05 ,,	,,	,,	29428·6
3396·1	1b	3396·13 ,,	,,	8·4	29437
3395·46	1n		,,	,,	29442·7
3394·72	1	3394·65 ,,	,,	,,	29449·1
3392·80	3	3392·74 ,,	,,	,,	29465·8
3392·43	2	3392·37 ,,	,,	,,	29469·0
3392·13	1	3392·12 ,,	,,	,,	29471·6
3389·85	1	3389·83 ,,	,,	,,	29491·4
3387·50	1	3387·48 ,,	,,	,,	29511·9
3384·11	2	3384·05 ,,	,,	,,	29541·5
3383·84	1	3383·80 ,,	,,	,,	29543·8
3383·00	1		,,	,,	29547·6
3382·52	1	3382·48 ,,	,,	,,	29555·4
3381·15	1n		,,	,,	29567·3
3380·25	3	3380·17 ,,	,,	,,	29575·2
3379·11	2	3379·11 ,,	,,	,,	29585·2
3378·76	2	3378·77 ,,	,,	,,	29588·3
3372·90	1	3372·90 ,,	0·94	,,	29639·7
3372·18	1	3372·18 ,,	,,	,,	29646·0
3370·92	4	3370·87 ,,	,,	,,	29657·1
3369·69	3	3369·62 ,,	,,	,,	29667·9
3366·92	2	3366·88 ,,	,,	,,	29692·3
3361·31	1	3361·03 ,,	,,	,,	29741·9
3360·2	1b		,,	8·5	29752
3358·4	1b	3358·41 ,,	,,	,,	29768
3356·49	1	3356·44 ,,	,,	,,	29784·5

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3355·35	2	3355·27 K. & R.	0·94	8·5	29794·7
3354·14	1	3354·16 ,,	,,	,,	29805·4
3351·89	1	} 3351·85 { ,,	,,	,,	29825·4
3351·83	1	,,	,,	,,	29826·0
3351·63	1	3351·65 ,,	,,	,,	29827·7
3349·48	1		,,	,,	29846·9
3349·11	1		,,	,,	29850·2
(3348·01)	1	3348·03 ,,	,,	,,	29860·0
3347·00	1	3347·03 ,,	,,	,,	29869·0
3342·37	1	3342·35 ,,	,,	,,	29883·4
3341·99	1	3342·01 ,,	,,	,,	29913·8
3340·65	1	3340·64 ,,	,,	,,	29925·8
3339·28	1	3339·24 ,,	,,	,,	29938·1
3338·65	1b	3338·76 ,,	0·95	,,	29943·7
3337·86	1	3337·73 ,,	,,	,,	29950·8
3336·33	1	3336·30 ,,	,,	,,	29964·6
3335·36	1		,,	,,	29973·3
3334·32	1	3334·31 ,,	,,	,,	29982·6
3331·70	1	3331·74 ,,	,,	,,	30006·2
3328·95	2	3329·00 ,,	,,	,,	30031·0
3325·56	1	3325·56 ,,	,,	,,	30061·6
3324·65	1	3324·62 ,,	,,	8·6	30069·8
3323·87	1		,,	,,	30076·8
3323·83	2	3323·84 ,,	,,	,,	30077·2
3323·21	2		,,	,,	30082·8
3322·65	1n	3322·65 ,,	,,	,,	30087·9
3319·40	1	3319·35 ,,	,,	,,	30117·3
3318·7	1b		,,	,,	30124
3316·21	1		,,	,,	30146·3
3314·87	2	3314·86 ,,	,,	,,	30158·5
3310·57	1	3310·53 ,,	,,	,,	30197·7
3310·48	1		,,	,,	30198·5
3307·85	1	3307·87 ,,	,,	,,	30222·5
3306·49	6	3306·50 ,,	,,	,,	30235·0
3306·10	6	3306·09 ,,	,,	,,	30238·5
3303·65	1n	3303·69 ,,	,,	,,	30260·9
3303·00	1n		,,	,,	30266·9
3302·0	1b	3302·02 ,,	,,	,,	30276
3301·3	1b	3301·35 ,,	,,	,,	30283
3298·26	1	3298·25 ,,	0·92	,,	30310·4
3298·04	1		,,	,,	30312·4
3297·00	1	3296·91 ,,	,,	,,	30322·0
3295·95	1	3295·94 ,,	,,	,,	30331·7
3295·35	1n		,,	,,	30337·2
3292·74	2	3292·70 ,,	,,	,,	30361·2
3292·16	2	3292·13 ,,	,,	,,	30366·6
3291·15	1	3291·10 ,,	,,	,,	30375·9
3289·49	2	3289·51 ,,	,,	,,	30391·3
3286·90	5	3286·87 ,,	,,	8·7	30415·1
3285·65	1	3285·50 ,,	,,	,,	30426·7
3284·72	1	3284·71 ,,	,,	,,	30435·3
3283·02	1	3283·00 ,,	,,	,,	30451·1
3281·44	2	3281·40 ,,	,,	,,	30465·7
3280·42	2	3280·37 ,,	,,	,,	30475·2
3279·8	1b	3279·87 ,,	,,	,,	30481

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3278·87	1n	3278·83 K. & R.	0·92	8·7	30489·6
3277·48	3	3277·42 ,,	,,	,,	30502·6
3276·75	1n	3276·55 ,,	,,	,,	30509·3
3274·11	3	3274·05 ,,	,,	,,	30534·0
3273·70	1n		,,	,,	30537·8
3271·16	3	3271·12 ,,	,,	,,	30561·5
3268·67	1n		,,	,,	30584·8
3268·34	1	3268·33 ,,	,,	,,	30587·9
3267·13	1		,,	,,	30599·2
3267·06	1		,,	,,	30599·9
3265·76	3	3265·73 ,,	,,	,,	30612·0
3265·16	1	3265·15 ,,	,,	,,	30617·7
3264·64	1	3264·60 ,,	,,	,,	30622·5
3262·45	1	3262·40 ,,	,,	,,	30643·1
3260·40	1	3260·32 ,,	,,	,,	30662·4
3260·11	1	3260·09 ,,	,,	,,	30665·1
3259·20	3	3259·15 ,,	0·91	,,	30673·7
3258·90	3		,,	,,	30676·5
3257·73	1	3257·69 ,,	,,	,,	30687·5
3256·01	2	3255·97 ,,	,,	,,	30703·7
(3254·50)	2	3254·47 ,,	,,	,,	30718·0
3253·75	1	3253·70 ,,	,,	,,	30725·1
3253·06	1	3253·00 ,,	,,	,,	30731·6
3251·40	1	3251·31 ,,	,,	8·8	30747·2
3250·80	1n	3250·75 ,,	,,	,,	30752·9
3249·81	1	3249·94 ,,	,,	,,	30762·2
3249·35	1n	3249·27 ,,	,,	,,	30766·6
3248·31	1	3248·31 ,,	,,	,,	30776·4
3247·66	3	3247·70 ,,	,,	,,	30782·6
3247·32	3	3247·39 ,,	,,	,,	30785·8
3247·10	1	3247·08 ,,	,,	,,	30787·9
3246·60	1n	3246·55 ,,	,,	,,	30792·7
3246·12	1	3246·09 ,,	,,	,,	30797·2
3244·31	2	3244·27 ,,	,,	,,	30814·4
3243·85	2	3243·94 ,,	,,	,,	30818·8
3239·55	3	3239·53 ,,	,,	,,	30859·7
3237·95	2	3237·92 ,,	,,	,,	30874·9
3237·53	1	3237·43 ,,	,,	,,	30878·9
3236·70	1n	3236·88 ,,	,,	,,	30886·9
3236·33	1	3236·31 ,,	,,	,,	30890·4
3234·72	1	3234·71 ,,	,,	,,	30905·8
3234·11	1	3234·07 ,,	,,	,,	30911·6
3233·19	2	3233·14 ,,	,,	,,	30920·4
3232·94	1		,,	,,	30922·8
3231·85	1	3231·72 ,,	,,	,,	30933·2
3231·12	2	3231·05 ,,	,,	,,	30940·2
3230·36	1	3230·29 ,,	,,	,,	30947·5
3230·14	1		,,	,,	30949·6
3230·00	1n	3230·01 ,,	,,	,,	30951·0
3229·27	1	3229·19 ,,	,,	,,	30958·0
3229·03	1	3228·97 ,,	,,	,,	30960·3
3228·36	1	3228·36 ,,	,,	,,	30966·7
3227·92	6	3227·88 ,,	,,	,,	30970·9
3225·90	5	3225·90 ,,	,,	,,	30990·3
3222·19	4	3222·12 ,,	,,	,,	31026·0

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3219·93	2	3219·92 K. & R.	0·90	8·8	31047·8
3219·67	2	3219·67 ,,	,,	,,	31050·3
3217·47	2	3217·49 ,,	,,	,,	31071·5
3216·04	2	3216·03 ,,	,,	8·9	31085·2
3214·49	1	3214·48 ,,	,,	,,	31100·2
3214·13	3	3214·14 ,,	,,	,,	31103·7
3213·45	5	3213·43 ,,	,,	,,	31110·3
3212·13	3	3212·08 ,,	,,	,,	31123·1
3211·82	1	3211·77 ,,	,,	,,	31125·5
3210·94	1	3210·92 ,,	,,	,,	31134·6
3210·56	3	3210·35 ,,	,,	,,	31138·3
3210·35	1	3210·35 ,,	,,	,,	31140·4
3209·45	1	3209·45 ,,	,,	,,	31149·1
3208·6	1n	3208·60 ,,	,,	,,	31157
3205·50	2	3205·45 ,,	,,	,,	31187·5
3202·75	1	3202·65 ,,	,,	,,	31222·8
3200·58	2	3200·58 ,,	,,	,,	31235·4
3199·63	1	3199·62 ,,	,,	,,	31244·7
3197·06	3	3197·04 ,,	,,	,,	31268·9
3196·21	3	3196·24 ,,	,,	,,	31278·1
3193·95	3	3193·92 ,,	,,	,,	31300·3
3193·39	2	3193·37 ,,	,,	,,	31305·7
3193·05	2	3192·93 ,,	,,	,,	31309·1
3192·15	1n		,,	,,	31317·9
3191·77	1	3191·77 ,,	,,	,,	31321·7
3190·95	1n	3190·80 ,,	,,	,,	31329·7
3188·92	1	3188·96 ,,	,,	,,	31349·7
3188·70	1n	3188·67 ,,	,,	,,	31351·8
3187·40	1	3187·35 ,,	,,	,,	31364·6
3186·87	3	3186·83 ,,	,,	,,	31369·9
3185·43	1n	3185·34 ,,	,,	,,	31384·0
3184·98	1	3185·00 ,,	,,	,,	31388·5
3183·24	1	3183·11 ,,	,,	,,	31405·6
3181·67	1	3181·60 ,,	0·89	,,	31421·1
3180·85	1n	3180·85 ,,	,,	9·0	31429·1
3180·32	2	3180·30 ,,	,,	,,	31434·4
3179·61	2	3179·61 ,,	,,	,,	31441·4
3179·07	1	3179·06 ,,	,,	,,	31446·7
3178·09	1	3178·08 ,,	,,	,,	31456·4
3177·64	3	3177·64 ,,	,,	,,	31460·9
3175·54	1	3175·53 ,,	,,	,,	31481·7
3171·43	1	3171·44 ,,	,,	,,	31522·5
3170·47	1	3170·43 ,,	,,	,,	31532·1
3167·96	4	3167·97 ,,	,,	,,	31557·1
3166·52	1	3166·55 ,,	,,	,,	31571·4
3165·95	1n	3165·97 ,,	,,	,,	31577·1
3162·90	1		,,	,,	31607·6
3162·05	1	3162·04 ,,	,,	,,	31616·1
3160·74	1	3160·74 ,,	,,	,,	31629·2
3159·0	1b	3159·08 ,,	,,	,,	31647
3157·97	1n	3157·99 ,,	,,	,,	31656·9
3157·12	1	3157·15 ,,	,,	,,	31665·4
(3154·32)	5	3154·29 ,,	,,	,,	31693·6
3153·33	1n	3153·31 ,,	,,	,,	31703·5
3151·45	1	3151·42 ,,	,,	,,	31722·4

Iron—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3144·88	1	3144·61 K. & R.	0·89	9·1	31788·6
3144·08	1	3144·06 ,,	,,	,,	31796·7
3142·95	1	3142·97 ,,	,,	,,	31808·1
3142·52	1n	3142·54 ,,	,,	,,	31812·5
3140·48	1n	3140·47 ,,	0·88	,,	31833·2
3140·00	1n	3140·00 ,,	,,	,,	31838·0
3135·49	2	3135·51 ,,	,,	,,	31883·8
3134·20	1	3134·21 ,,	,,	,,	31897·0
3133·17	1n		,,	,,	31907·5
3126·25	1n	3126·25 ,,	,,	,,	31978·1
3125·77	1	3125·77 ,,	,,	,,	31983·0
3120·50	1	3120·54 ,,	,,	,,	32037·0
3119·60	1	3119·58 ,,	,,	,,	32046·3
3116·70	1	3116·73 ,,	,,	,,	32076·1
3114·40	1		,,	9·2	32099·7
3106·65	1n	3106·59 ,,	,,	,,	32079·8
3105·65	1n	3105·69 ,,	,,	,,	32090·2
3105·25	1n		,,	,,	32194·3
3100·76	2	3100·77 ,,	0·87	,,	32241·0
3100·44	2		,,	,,	32244·3
3100 05	2	3100·04 ,,	,,	,,	32248·3
3098·30	1	3098·25 ,,	,,	,,	32266·6
3096·45	1		,,	,,	32285·8
3091·70	2	3091·67 ,,	,,	,,	32335·5
3089·5	1n	3089·64 ,,	,,	,,	32359
3083·85	2	3083·81 ,,	,,	9·3	32417·7
3078·9	1b		,	,,	32470
3077·30	2	3077·32 ,,	,,	,,	32486·7
3075·84	2	3075·80 ,,	,,	,,	32502·1
3068·27	1n	3068·25 ,,	,,	,,	32582·4
3067·35	3	3067·30 ,,	,,	,,	32592·1
3065·50	1n	3065·40 ,,	,,	,,	22611·8
3062·33	2	{3062·47 3062·29} ,,	0·86	,,	32645·6
3059·20	3	3059·19 ,,	,,	,,	32679·0
3057·56	3	3057·55 ,,	,,	,,	32696·5
3056·95	1n		,,	,,	32703·0
3055·40	1	3055·35 ,,	,,	,,	32719·6
3053·17	1	3053·15 ,,	,,	,,	32743·4
(3047·72)	3	3047·71 ,,	,,	9·4	32802·0
3045·1	1b	3045·16 ,,	,,	,,	32830
3042·77	1	3042·75 ,,	,,	,,	32855·4
3042·12	1	3042·13 ,,	,,	,,	32862·5
3041·88	1	3041·83 ,,	,,	,,	32865·0
3041·80	1		,,	,,	32865·9
3040·55	1	3040·54 ,,	,,	,,	32879·4
3037·50	3	3037·54 ,,	,,	,,	32912·4
3031·75	1	3031·74 ,,	,,	,,	32974·9
3031·34	1	3031·31 ,,	,,	,,	32979·3
3030·25	1	3030·24 ,,	,,	,,	32991·2
3026·57	1	3026·57 ,,	,,	,,	33031·3
3025·96	2	3026·00 ,,	,,	,,	33038·0
3025·75	1	3025·75 ,,	,,	,,	33040·3
3024·14	1	3024·13 ,,	,,	9·5	33057·7
3021·18	2	3021·15 ,,	0·85	,,	33090·1

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3020·79	2	3020·70 K. & R.	0·85	9·5	33094·4
3020·60	2		,,	,,	33096·5
3019·11	1	3019·08 ,,	,,	,,	33112·8
3017·73	1	3017·72 ,,	,,	,,	33128·0
3016·30	1	3016·29 ,,	,,	,,	33143·7
3016·05	1n	3016·04 ,,	,,	,,	33146·4
3011·60	1	3011·57 ,,	,,	,,	33195·4
3009·70	2	3009·66 ,,	,,	,,	33216·4
3008·26	2	3008·23 ,,	,,	,,	33232·3
3007·42	1	3007·30 ,,	,,	,,	33241·6
3003·19	1	3003·14 ,,	,,	,,	33288·4
3002·80	3	3002·74 ,,	,,	,,	33292·8
3001·08	2	3001·05 ,,	,,	,,	33311·8
3000·57	1	3000·56 ,,	,,	,,	33317·5
3000·20	1n		,,	,,	33321·6
2999·65	2	2999·61 ,,	,,	,,	33327·7
2997·45	1	2997·51 ,,	,,	9·6	33352·1
2994·56	3	2994·54 ,,	,,	,,	33384·3
2990·51	1	2990·48 ,,	,,	,,	33429·5
2987·41	1	2987·40 ,,	,,	,,	33464·2
2985·70	4	2985·65 ,,	,,	,,	33483·4
2984·97	6	2984·92 ,,	,,	,,	33491·6
2983·71	2	2983·68 ,,	,,	,,	33504·7
2982·20	1	2982·31 ,,	0·84	,,	33522·7
2981·59	1	2981·54 ,,	,,	,,	33529·5
2981·12	1n		,,	,,	33534·8
2980·70	1n	2980·62 ,,	,,	,,	33539·6
2979·48	1	2979·44 ,,	,,	,,	33553·3
2976·70	1	2976·66 ,,	,,	,,	33584·6
2976·05	1		,,	,,	33592·0
2973·39	2	2973·41 ,,	,,	,,	33622·0
2973·28	2	2973·17 ,,	,,	,,	33623·3
2970·64	2	2970·60 ,,	,,	9·7	33653·1
2970·25	2	2970·20 ,,	,,	,,	33657·5
2970·05	1		,,	,,	33659·8
2969·63	1		,,	,,	33664·5
2969·53	1	2969·52 ,,	,,	,,	33665·7
2967·03	2	2966·99 ,,	,,	,,	33694·0
2965·39	1	2965·35 ,,	,,	,,	33712·7
2965·17	2	2965·12 ,,	,,	,,	33715·2
2964·76	1	2964·72 ,,	,,	,,	33719·8
2964·25	1	2964·30 ,,	,,	,,	33725·6
2961·40	1	2961·30 ,,	,,	,,	33758·1
2960·11	1	2960·07 ,,	,,	,,	33772·8
2959·70	1	2959·76 ,,	,,	,,	33777·5
(2957·49)	1	2957·48 ,,	,,	,,	33802·8
2954·06	2	2953·99 ,,	,,	,,	33842·0
2953·88	3	2953·86 ,,	,,	,,	33844·1
2950·35	1n	2950·34 ,,	,,	,,	33884·6
2949·30	2	2949·28 ,,	,,	,,	33896·7
2948·52	1	2948·52 ,,	,,	,,	33905·6
2948·00	2	2948·00 ,,	,,	,,	33911·6
2947·78	3	2947·77 ,,	,,	,,	33914·1
2944·55	4	2944·49 ,,	,,	9·8	33951·2
2941·46	1	2941·42 ,,	0·83	,,	33986·9

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2939·62	1		0·83	9·8	34008·2
(2937·02)	2	2936·99 K. & R.	,,	,,	34038·3
2931·75	1n		,,	,,	34099·5
2929·13	2	2929·20 ,,	,,	,,	34130·0
2926·71	3	2926·65 ,,	,,	,,	34158·3
2925·52	1	2925·43 ,,	,,	,,	34172·2
2923·99	1	2923·94 ,,	,,	,,	34190·0
2923·43	1	2923·39 ,,	,,	,,	34196·6
2922·16	1		,,	,,	34211·5
2920·82	1	2920·76 ,,	,,	9·9	34227·1
2918·14	1	2918·11 ,,	,,	,,	34258·5
2917·65	1n	2917·58 ,,	,,	,,	34264·3
2917·20	1n		,,	,,	34269·6
2912·27	1	2912·26 ,,	,,	,,	34327·6
2910·9	1b		,,	,,	34344
2907·98	1	2907·94 ,,	,,	,,	34378·2
2907·60	1	2907·59 ,,	,,	,,	34382·7
2906·25	1	2906·23 ,,	,,	,,	34398·7
2902·57	1n	2902·55 ,,	0·82	,,	34442·3
2902·03	1n	2902·02 ,,	,,	,,	34448·7
2901·52	1	2901·46 ,,	,,	,,	34454·8
2899·50	1	2899·49 ,,	,,	,,	34478·8
2897·37	2	2897·69 ,,	,,	,,	34504·2
2895·35	2		,,	10·0	34528·1
2895·17	1	2895·11 ,,	,,	,,	34530·3
2894·90	2		,,	,,	34533·5
2894·65	1	2894·59 ,,	,,	,,	34536·5
2892·95	1	2892·89 ,,	,,	,,	34556·8
2888·20	1		,,	,,	34613·6
2887·95	1	2887·88 ,,	,,	,,	34616·6
2887·4	1n	2887·43 ,,	,,	,,	34623
2886·32	1	2886·38 ,,	,,	,,	34636·2
2886·02	1		,,	,,	34639·8
2884·9	1b		,,	,,	34653
2883·80	3	2883·80 ,,	,,	,,	34666·5
2880·89	3	2880·84 ,,	,,	,,	34701·5
2879·35	1		,,	,,	34720·1
2877·38	1	2877·37 ,,	,,	,,	34743·8
2876·86	2	2876·80 ,,	,,	,,	34750·1
2875·44	2	2875·35 ,,	,,	,,	34767·3
2874·27	1	2874·24 ,,	,,	,,	34781·4
2873·49	4	2873·48 ,,	,,	,,	34790·9
2872·47	3	2872·38 ,,	,,	10·1	34803·1
2871·19	2	2871·16 ,,	,,	,,	34818·7
2870·70	1		,,	,,	34824·6
2869·40	1	2869·38 ,,	,,	,,	34840·4
2869·28	1		,,	,,	34841·9
2868·96	1	2868·94 ,,	,,	,,	34845·7
2868·52	1	2868·50 ,,	,,	,,	34851·1
2866·82	1	2866·68 ,,	,,	,,	34871·8
2865·05	1		,,	,,	34893·3
2864·4	1b		0·81	,,	34901
2863·95	1	2863·92 ,,	,,	,,	34906·7
2863·53	1	2863·46 ,,	,,	,,	34911·8
2861·26	1	2861·29 ,,	,,	,,	34939·5

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2858·95	1n	2858·96 K. & R.	0·81	10·1	34967·8
2858·40	5	2858·41 „	„	„	34974·5
2857·53	1		„	„	34985·2
2857·28	2	2857·29 „	„	„	34988·2
2857·07	1n	2857·09 „	„	„	34990·8
2856·52	1n		„	„	34997·5
2856·25	1	2856·19 „	„	„	35000·8
2855·77	3	2855·75 „	„	„	35006·7
2853·85	1n	2853·81 „	„	„	35030·3
2853·33	1n		„	„	35036·7
2853·02	1n	2853·02 „	„	„	35040·5
2852·24	1 Mg	2852·19 „	„	„	35050·1
(2851·90)	2	2851·85 „	„	„	35054·2
2849·70	2	2849·67 „	„	„	35081·3
2849·02	1		„	„	35089·7
2848·52	2b	2848·77 „	„	„	35095·9
2848·15	2	2848·13 „	„	10·2	35100·3
2847·34	1		„	„	35110·3
2845·8	2b	2845·75 „	„	„	35129
2845·72	1		„	„	35130·3
2845·51	1n		„	„	35132·9
2844·08	2	2844·04 „	„	„	35150·6
2843·75	1		„	„	35154·7
2843·58	1	2843·69 „	„	„	35156·7
2843·43	1n	2843·30 „	„	„	35158·6
2842·85	1n	2842·96 „	„	„	35165·8
2842·20	1	2842·46 „	„	„	35173·8
2841·47	1	2841·32 „	„	„	35182·9
2840·82	3	2840·73 „	„	„	35190·9
2840·46	2	2840·50 „	„	„	35195·4
2839·85	2b	2839·66 „	„	„	35202·9
(2838·23)	1	2838·19 „	„	„	35223·0
2837·43	1		„	„	35233·0
2836·63	1		„	„	35242·9
2836·31	1	2836·45 „	„	„	35246·9
2835·82	4	2835·76 „	„	„	35253·0
2835·58	1	2835·51 „	„	„	35256·0
2833·3	1b		„	„	35284
2832·57	2	2832·47 „	„	„	35293·4
2831·67	5		„	„	35304·6
2831·15	1	2831·04 „	„	„	35311·1
2828·75	3	2828·87 „	„	„	35341·1
2828·02	1	2827·98 „	„	„	35350·2
2827·55	2	2827·68 „	„	„	35356·1
2826·16	1	2826·07 „	„	„	35373·5
2825·85	1	2825·75 „	„	„	35377·4
2825·66	2	2825·60 „	0·80	„	35379·8
2823·41	3	2823·32 „	„	10·3	35407·9
2819·45	1	2819·35 „	„	„	35457·6
2817·60	1n	2817·55 „	„	„	35480·9
2817·25	1n		„	„	35485·3
2813·74	1	2813·67 „	„	„	35529·6
2813·40	2	2813·36 „	„	„	35533·9
2812·2	1n	2812·36 „	„	„	35549
2811·36	1	2811·23 „	„	„	35559·7

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2810·0	1b		0·80	10·3	35577
2807·10	2	2807·03 K. & R.	,,	,,	35613·7
2805·91	1	2805·87 ,,	,,	,,	35628·8
2805·44	1n		,,	,,	35634·7
2805·02	1		,,	,,	35640·1
2804·64	2	2804·56 ,,	,,	,,	35644·9
2804·13	1n	2804·13 ,,	,,	,,	35651·4
2803·72	1n	2803·68 ,,	,,	,,	35656·6
2802·82	2 Mg ?	2802·76 ,,	,,	,,	35668·1
2801·18	1n Mn	2801·15 ,,	,,	,,	35688·9
2800·9	1n	2800·73 ,,	,,	,,	35693
2799·83	1	2799·87 ,,	,,	,,	35706·2
2799·42	2	2799·34 ,,	,,	10·4	35710·9
2798·40	1 Mn	2798·31 ,,	,,	,,	35724·3
2798·06	1		,,	,,	35728·6
2797·92	1	2797·82 ,,	,,	,,	35730·4
2797·5	1b		,,	,,	35736
2796·9	1b	2796·91 ,,	,,	,,	35744
2795·65	3 Mg	2795·58 ,,	,,	,,	35759 5
2794·9	1n	2795·00 ,,	,,	,,	35769
2794·02	3	2793·97 ,,	,,	,,	35780·3
2793·40	1		,,	,,	35788·3
2792·55	1	2792·44 ,,	,,	,,	35799·2
2791·94	1	2791·84 ,,	,,	,,	35807·0
2791·65	1	2791·51 ,,	,,	,,	35810·7
2791·20	1		,,	,,	35816·5
2790·70	1		,,	,,	35812·9
2789·87	1	2789·87 ,,	,,	,,	35833·6
2788·23	3n	2788·19 ,,	,,	,,	35854·6
2787·5	1b		,,	,,	35864·0
2785·46	3n	2785·25 ,,	,,	,,	35890·3
2784·43	1	2784·40 ,,	,,	,,	35903·0
2783·81	7	2783·75 ,,	,,	,,	35911·5
2781·96	1	2781·89 ,,	,,	,,	35935·5
2780·9	1b	2780·93 ,,	,,	,,	35949·2
2780·19	1	2780·28 ,,	,,	,,	35958·5
2780·07	1		,,	,,	35959·9
2779·40	5	2779·34 ,,	,,	,,	35968·6
2778·96	1	2778·89 ,,	,,	,,	35974·3
2778·34	2	2778·29 ,,	,,	,,	35982·3
2778·01	2	2778·15 ,,	,,	,,	35986·6
2777·15	1b		,,	,,	35997·7
2776·31	1	2776·47 ,,	,,	,,	36008·6
2775·5	1n		,,	10·5	36019·0
2774·82	3	2774·76 ,,	,,	,,	36027·9
2773·38	1	2773·28 ,,	,,	,,	36043·6
2772·6	1n	2772·56 ,,	,,	,,	36056·7
2772·23	2	2772·15 ,,	,,	,,	36061·5
2771·70	1		,,	,,	36068·4
2771·34	1	2771·30 ,,	,,	,,	36073·1
2770·64	2	2770·75 ,,	,,	,,	36081·2
2769·49	4	2769·37 ,,	,,	,,	36097·2
2769·03	3	2768·98 ,,	,,	,,	36103·2
2768·50	1	2768·52 ,,	,,	,,	36110·1
2767·62	7r	2767·56 ,,	,,	,,	36121·6

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2767·06	1	2766·99 K. & R.	0·80	10·5	36128·9
2766·3	1b	2766·45 "	"	"	36138·9
2765·6	1b	2765·73 "	"	"	36148·0
2764·93	1	2764·80 "	"	"	36156·8
2764·50	1	2764·41 "	"	"	36162·3
2764·05	1		"	"	36168·3
2763·25	1	2763·17 "	"	"	36178·7
2762·60	1	2762·82 "	"	"	36187·3
2762·19	2	2762·12 "	"	"	36192·7
2761·88	3	2761·83 "	"	"	36196·7
2761·00	1	2760·96 "	"	"	36221·4
2759·95	1	2759·86 "	"	"	36222·0
2759·45	1n	2759·42 "	"	"	36228·6
2758·60	1n		"	"	36239·8
2758·02	1n	2757·91 "	"	"	36247·4
2757·45	2		"	"	36254·9
2757·16	2	2757·09 "	"	"	36258·7
2756·65	1	2756·85 "	"	"	36265·4
2756·45	2		"	"	36268·0
2755·82	10	2755·77 "	"	"	36276·5
2754·55	1	2754·48 "	"	"	36294·1
2754·19	1	2754·09 "	"	"	36298·0
2753·83	1	2753·74 "	"	"	36302·6
2753·32	7	2753·37 "	"	"	36309·3
2752·3	1b	2752·20 "	"	"	36322·8
2751·26	2	2751·20 "	"	10·6	36336·4
(2750·24)	1	2750·21 "	"	"	36349 9
2749·40	10	2749·42 "	"	"	36361·0
2747·08	7	2747·03 "	"	"	36391·4
2746·58	7	2746·54 "	"	"	36398·3
2744 98	1	2745·13 "	"	"	36419·5
2744·60	1	2744·60 "	"	"	36424·6
2744·15	1	2744·12 "	"	"	36430·6
2743·34	8	2743·23 "	"	"	36441·4
2742·51	2	2742·45 "	"	"	36452·4
2742·36	1		"	"	36454·4
2741·46	2	2741·48 "	"	"	36466·3
2739·67	10	2739·59 "	"	"	36490·1
2737·74	1	2737·72 "	"	"	36515·9
2737·43	2	2737·37 "	"	"	36520·0
2737·05	5	2737·02 "	"	"	36525·1
2735·57	2	2735·61 "	"	"	36544·9
2734·92	1	2734·98 "	"	"	36553·5
2734·38	1	2734·39 "	"	"	36560·7
2734·12	1	2734·07 "	"	"	36564·2
2733·69	2	2733·65 "	"	"	36570·0
2733·06	1		"	"	36578·4
2732·59	1	2732·53 "	"	"	36584·7
2732·15	1	2731·93 "	"	"	36590·6
2730·85	4	2730·79 "	"	"	
2729·70	1n		"	"	36623·5
2728·99	2	2728·90 "	"	"	36633·0
2728·10	1	2728·11 "	"	"	36644·9
2727·59	8	2727·61 "	"	10·7	36651·7
2726·62	1		"	"	36664·7

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2726·34	1		0·80	10·7	36668·5
2726·15	1	2726·20 K. & R.	,,	,,	36672·3
2724·99	4	2724·97 ,,	,,	,,	36686·7
2723·69	2	2723·66 ,,	,,	,,	36704·2
2722·86	2		,,	,,	36715·4
2722·18	2	2722·10 ,,	,,	,,	36714·5
2721·94	1		,,	,,	36727·8
2721·00	3	2720·99 ,,	,,	,,	36740·5
2720·30	1	2720·28 ,,	,,	,,	36749·9
2719·40	2	2719·51 ,,	,,	,,	36762·1
2719·13	2	2719·11 ,,	,,	,,	36765·7
2718·73	1		,,	,,	36771·2
2718·54	1	2718·51 ,,	,,	,,	36773·6
2718·2	1b		,,	,,	36778·3
2716·77	1n		,,	,,	36897·7
2716·30	4	2716·31 ,,	,,	,,	36804·1
2714·51	7	2714·48 ,,	,,	,,	36828·3
2712·48	2	2712·42 ,,	,,	,,	36855·9
2711·94	4	2711·92 ,,	,,	,,	36863·3
2710·66	1	2710·61 ,,	,,	,,	36880·7
2710·0	1b	2710·08 ,,	,,	,,	36989·7
2709·51	1	2709·47 ,,	,,	,,	36996·3
2709·14	3	2709·13 ,,	,,	,,	36901·4
2708·69	1	2708·64 ,,	,,	,,	36907·5
2707·23	3	2707·13 ,,	,,	,,	36926·8
(2706·68)	3	2706·63 ,,	,,	,,	36934·9
2706·14	1	2706·07 ,,	,,	,,	36942·3
2704·66	1	2704·80 ,,	,,	,,	36962·5
2704·10	5	2704·06 ,,	,,	,,	36970·1
2701·8	1b	2701·99 ,,	,,	,,	37001·7
2701·4	1b		,,	,,	37007·1
*2699·22	1	2699·18 ,,	,,	,,	37037·0
*2697·52	2	2697·58 ,,	,,	,,	37060·4
2696·35	1	2696·41 ,,	,,	,,	37076·5
2696·1	1n	2696·12 ,,	,,	,,	37079·9
2695·4	1b	2695·64 ,,	,,	10·8	37089·4
2694·5	1b	2694·63 ,,	,,	,,	37101·8
2693·96	1		,,	,,	37109·3
2692·92	2	2692·91 ,,	,,	,,	37123·6
2692·68	6	2692·71 ,,	,,	,,	37126·9
2691·83	1	2691·80 ,,	,,	,,	37138·6
2690·17	1	2690·17 ,,	,,	,,	37161·6
2689·93	1	2689·92 ,,	,,	,,	37165·2
2689·26	3	2689·28 ,,	,,	,,	37174·1
2686·5	1n		,,	,,	37212·4
2686·2	1n		,,	,,	37216·5
2684·84	6	2684·86 ,,	,,	,,	37235·3
2683·10	1		,,	,,	37259·5
2682·63	2		,,	,,	37266·1
2681·16	1n		,,	,,	37286·5
2680·98	1n	2680·99 ,,	,,	,,	37289·0
2680·77	1n		,,	,,	37292·0
2680·55	1n	2680·53 ,,	,,	,,	37295·0
(2679·15)	2	2679·14 ,,			37314·0
2677·00	1	2676·97 ,,	,,	10·9	37444·3

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2672·7	1n		0·80	10·9	37404·5
2672·3	1n	2672·30 K. & R.	"	"	37410·0
2671·6	1n	2671·49 "	"	"	37419·9
2670·52	1	2670·59 "	"	"	37434·8
2670·05	1	2670·00 "	"	"	37441·6
2669·60	1	2669·55 "	"	"	37447·9
2669·3	1b		"	"	37452·1
2667·45	1n	2667·36 "	"	"	37478·1
2666·75	7	2666·72 "	"	"	37487·9
2665 77	1n	2665·87 "	"	"	37501·7
2664·78	7	2664·74 "	"	"	37515·6
2664·34	2		"	"	37521·8
2662·8	1n		"	"	37543·6
2662·13	1n	2662·13 "	"	"	37557·0
2660·50	1b	2660·48 "	"	"	37576·0
2658·38	3	2658·48 "	"	"	37606·0
2658·05	1		"	"	37610·6
2656·26	1n	2656·22 "	"	"	37636·0
2656·0	1b		"	"	37639·7
2654·8	1b		"	11·0	37656·6
2653·8	1b	2653·87 "	"	"	37670·8
2652·68	1	2652·53 "	"	"	37686·7
2651·82	1	2651·78 "	"	"	37798·9
2650·70	2b		"	"	37714 9
2649·59	3		"	"	37730·7
2647·70	1n	2647·64 "	"	"	37757·6
2646·36	1	2646·40 "	"	"	37772·5
2645 49	2	2645·52 "	"	"	37889·2
2645·26	2		"	"	37892·4
2644·12	2	2644·07 "	"	"	37808·8
2642·13	3		"	"	37837·2
2641·77	1n	2641·74 "	"	"	37842·4
2641·23	1n	2641·13 "	"	"	37850·1
2639·66	3	2639·60 "	"	"	37872·7
2637·72	4	2637·69 "	"	"	37800·5
2636·82	1n		"	"	37813·5
2636·68	1n	2636·54 "	"	"	37815·5
2635·91	2	2635·87 "	"	"	37826·6
2635·50	2		"	"	37932·4
2635·07	1n	2635·00 "	"	"	37938·6
2634·00	1		"	"	37954·0
2633·75	1	2633·68 "	"	"	37957·8
2633·31	2		"	"	37964·0
2632·70	1	2632·66 "	"	"	37972·8
2632·35	1	2632·30 "	"	"	37977·8
2631·79	3	2631·72 "	"	11·1	37985·0
2631·46	4	2631·37 "	"	"	38090·6
2631·14	4	2631·07 "	"	"	38095·2
2630·16	3	2630·13 "	"	"	38009·4
2629·67	5	2629·66 "	"	"	38016·5
2628·40	8	2628·35 "	"	"	38034·9
2626·60	3	2626·52 "	"	"	38060·9
2625·80	7	} 2625·72 " {	"	"	38072·5
2625·67	5		"	"	38074·4
2624·35	1	2624·21 "	"	"	38093·6

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
2623·88	2		0·80	11·1	38100·4
2623·65	2	2623·58 K. & R.	,,	,,	38103·3
2623·26	2		,,	,,	38110·4
2621·78	6	2621·72 ,,	,,	,,	38130·9
2620·81	3	2620·73 ,,	,,	,,	38145·0
2620·54	3	2620·47 ,,	,,	,,	38148·2
2620·27	2n		,,	,,	38152·9
2619·16	4	2619·06 ,,	,,	,,	38169·1
2618·16	1	2618·10 ,,	,,	,,	38183·7
2617·70	7	2617·70 ,,	,,	,,	38190·4
2616·49	1	2616·50 ,,	,,	,,	38208·0
2615·50	1	2615·50 ,,	,,	,,	38222·5
2615·00	1		,,	,,	38229·8
2614·60	1n	2614·62 ,,	,,	,,	38235·7
2613·91	9	2613·91 ,,	,,	,,	38245·8
2611·95	9	2611·94 ,,	,,	,,	38274·5
2611·16	3	2611·16 ,,	,,	,,	38286·0
2609·96	2	2609·79 ,,	,,	,,	38303·7
2609·57	1		,,	,,	38309·4
2609·20	2	2609·30 ,,	,,	11·2	38314·7
2608·92	1	2608·65 ,,	,,	,,	38318·8
2607·17	$9b^{v}$	2607·16 ,,	,,	,,	38344·6
2606·60	4	2606·92 ,,	,,	,,	38357·0
2606·03	1		,,	,,	38361·5
2605·44	5	2605·77 ,,	,,	,,	38370·0
2605·10	4		,,	,,	38375·2
2604·80	1n	2604·90 ,,	,,	,,	38379·5
2604·52	1		,,	,,	38383·5
2604·13	1		,,	,,	38393·9
2602·08	1n		,,	,,	38419·7
2601·25	1		,,	,,	38421·8
2600·55	1	2600·25 ,,	,,	,,	38442·2
2599·50	10r	2599·53 ,,	,,	,,	38457·7
2598·43	9	2598·44 ,,	,,	,,	38473·5
2596·87	1n	2596·60 ,,	,,	,,	38496·7
2595·75	1n		,,	,,	38413·6
2595·37	1	2595·41 ,,	,,	,,	38419·6
2595·06	1		,,	,,	38425·4
2594·17	1n	2594·20 ,,	,,	,,	38437·4
2593·80	4	2593·75 ,,	,,	,,	38442·5
2592·87	6	2592·90 ,,	,,	,,	38456·2
2591·65	6	2591·65 ,,	,,	,,	38474·6
2590·65	3	2590·65 ,,	,,	,,	38489·5
2588·87	2	2588·96 ,,	,,	,,	38415·8
2588·05	$5b^{v}$	2588·11 ,,	,,	,,	38627·9
2585·96	$8b^{v}$	2585·93 ,,	,,	11·3	38659·1
(2584·63)		2584·59 ,,	,,	,,	38678·9
2583·43	1		,,	,,	38796·9
2583·15	1		,,	,,	38701·1
2582·62	7	2582·50 ,,	,,	,,	38705·6
2581·22	2		,,	,,	38730·1
2580·82	1		,,	,,	38736·1
2580·6	1	2580·52 ,,	,,	,,	38739·4
2579·48	2n		,,	,,	38756·2
2579·22	2n	2579·35 ,,	,,	,,	38760·1

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2577·98	5		0·80	11·3	38778·8
2577·50	1	2577·41 K. & R.	"	"	38786·0
2576·89	5	2576·76 "	"	"	38895·2
2576·18	1 Mn	2576·20 "	"	"	38805·9
2575·83	1	2575·83 "	"	"	38811·1
2574·46	5	2574·43 "	"	"	38831·8
2573·85	1	2573·84 "	"	"	38841·0
2573·32	2	2573·23 "	"	"	38849·0
2573·06	2		"	"	38852·9
2572·3	1b		"	"	38864·4
2571·65	1	2571·67 "	"	"	38874·2
2570·94	4	2570·92 "	"	"	38885·0
2570·14	2		"	"	38997·1
2569·86	3	2569·73 "	"	"	38901·3
2568·96	2	2568·97 "	"	"	38915·0
2568·48	4	2568·49 "	"	11·4	38922·2
2567·01	4	2566·99 "	"	"	38944·4
2566·71	2		"	"	38949·0
2566·49	2		"	"	38952·3
2566·31	3		"	"	38955·0
2565·1	1n		"	"	38973·4
2563·95	2	2563·99 "	"	"	38990·9
2563·54	5	2563·53 "	"	"	38997·2
2562·59	6	2562·63 "	"	"	39011·6
2562·16	3	2562·35 "	"	"	39015·1
2561·70	1n	2561·87 "	"	"	39025·2
2561·02	1		"	"	39035·5
2560·39	4	2560·43 "	"	"	39045·2
2560·01	3		"	"	39051·0
2559·84	3	2559·91 "	"	"	39053·5
2559·35	2	2559·25 "	"	"	39061·0
2558·70	1	2558·60 "	"	"	39070·9
2557·60	3	2557·42 "	"	"	39087·8
2557·18	1	2556·92 "	"	"	39094·1
2556·40	1	2556·38 "	"	"	39106·1
2555·54	3	2555·59 "	"	"	39119·3
2555·12	3	2555·37 "	"	"	39125·7
2554·52	1	2555·04 "	"	"	39134·9
2553·85	2		"	"	39145·2
2553·30	2	2553·32 "	"	"	39153·6
2552·93	1		"	"	39159·3
2552·68	1	2552·74 "	"	"	39163·1
2552·06	1n		"	"	39171·6
2551·32	4	2551·19 "	"	"	39184·0
2550·87	5	2550·75 "	"	"	39190·9
2550·20	5	2550·07 "	"	"	39201·2
2549·60	4	2549·63 "	"	"	39210·4
2549·20	3		"	11·5	39216·6
2548·89	3		"	"	39221·3
2548·73	3	2548·76 "	"	"	39223·7
2548·42	3	2548·17 "	"	"	39228·5
2547·43	4	2547·06 "	"	"	39243·7
2546·80	5	2546·26 "	"	"	39253·5
2546·06	2	2545·95 "	"	"	39263·9
2545·60	2n		"	"	39270·4

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2545·32	3		0·80	11·5	39276·3
2545·05	3 Cu		,,	,,	39279·4
2544·82	1	2544·83 K. & R.	,,	,,	39284·0
2544·02	3	2544·02 ,,	,,	,,	39296·3
2543·49	5	2543·47 ,,	,,	,,	39304·6
2542·24	3	2542·20 ,,	,,	,,	39323·9
2541·91	5		,,	,,	39329·0
2541·20	5	2541·18 ,,	,,	,,	39340·0
2540·72	5	2540·90 ,,	,,	,,	39347·4
2539·91	1	2540·00 ,,	,,	,,	39360·0
2539·10	4		,,	,,	39372·5
2538·95	5	2538·98 ,,	,,	,,	39374·9
2538·65	2		,,	,,	39379·5
2538·25	4		,,	,,	39385·7
2537·3	3b	2537·21 ,,	,,	,,	39400·5
2536·95	5	2536·90 ,,	,,	,,	39405·9
2536·84	3		,,	,,	39407·5
2535·59	5	2535·67 ,,	,,	,,	39427·1
2534·50	6	2534·52 ,,	,,	,,	39444·0
2533·71	7	2533·86 ,,	,,	,,	39456·3
2532·2	1b	2532·37 ,,	,,	,,	39479·8
2531·16	1		,,	,,	39501 6
2530·77	2	2530·79 ,,	,,	,,	39502·1
2530·18	4	2530·03 ,,	,,	11·6	39511·2
2529·59	6	2529·65 ,,	,,	,,	39520·6
2529·36	2n	2529·40 ,,	,,	,,	39524·1
2529·24	2n	2529·03 ,,	,,	,,	39526·0
2528·58	1	2528·57 ,,	,,	,,	39536·3
2527·80	3	2527·67 ,,	,,	,,	39548·5
2527·51	3	2527·30 ,,	,,	,,	39553·0
2527·16	3		,,	,,	39558·5
2526·40	6	2526·30 ,,	,,	,,	39570·4
2526·16	2		,,	,,	39574·2
2525·95	1		,,	,,	39577·5
2525·50	7	2525·48 ,,	,,	,,	39584·5
2525·22	3n	2525·11 ,,	,,	,,	39588·9
2524·41	3	2524·52 ,,	,,	,,	39601·3
2523·76	3	2523·76 ,,	,,	,,	39611·8
2522·96	6	2522·93 ,,	,,	,,	39624·4
2522·31	2	2522·67 ,,	,,	,,	39634·6
2521·93	4	2521·97 ,,	,,	,,	39640·6
2521·60	2		,,	,,	39644·2
2521·22	5	2521·09 ,,	,,	,,	39651·8
2520·76	2		,,	,,	39659·0
2520·45	1n		,,	,,	39663·9
2519·70	2	2519·71 ,,	,,	,,	39675·7
2519·49	1	2519·30 ,,	,,	,,	39679·0
2519·14	5	2518·93 ,,	,,	,,	39684·5
2518·19	4	2518·25 ,,	,,	,,	39699·4
2517·75	1	2517·76 ,,	,,	,,	39706·5
2517·21	5	2517·21 ,,	,,	,,	39714·9
2516·68	1	2516·65 ,,	,,	,,	39723·4
2516·19	2	2516·19 ,,	,,	,,	39731·0
2515·21	2		,,	,,	39746·5
2514·95	2	2514·84 ,,	,,	,,	39750·6

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2514·49	6	2514·38 K. & R.	0·80	11·6	39757·9
2513·40	2n	2513·33 ,,	,,	,,	39775·1
2512·60	3	2512·38 ,,	,,	,,	39787·8
2511·85	7	2511·84 ,,	,,	11·7	39799·6
2511·46	1	2511·41 ,,	,,	,,	39805·8
(2510·93)	3	{2511·05 2510·87} ,,	,,	,,	39814·2
2510·00	1n		,,	,,	39828·9
2509·18	3	2509·43 ,,	,,	,,	39811·9
2508·82	1	2508·78 ,,	,,	,,	39847·7
2508·40	2		,,	,,	39854·3
2507·98	2	2507·99 ,,	,,	,,	39861·0
2507·73	1n		,,	,,	39863·9
2507·11	1		,,	,,	39874·8
2506·95	1n	2506·98 ,,	,,	,,	39877·4
2506·53	1 Cu		,,	,,	39883·9
2506·15	4	2506·25 ,,	,,	,,	39890·1
2505·30	2		,,	,,	39903·7
2505·05	1n	2505·09 ,,	,,	,,	39907·6
2503·97	5	2503·89 ,,	,,	,,	39924·9
2503·67	3	2503·89 ,,	,,	,,	39929·7
2503·39	4	2503·50 ,,	,,	,,	39934·1
2502·49	4	2502·53 ,,	,,	,,	39948·5
2501·79	1	2501·87 ,,	,,	,,	39979·7
2501·55	1		,,	,,	39963·5
2501·25	2		,,	,,	39968·3
2501·00	3	2501·00 ,,	,,	,,	39972·3
2500·47	1n		,,	,,	39979·8
2499·98	1		,,	,,	40088·6
2498·95	7b^{r}	2498·96 ,,	,,	,,	40005·1
2498·46	1	2498·37 ,,	,,	,,	40013·0
2497·88	5	2497·88 ,,	,,	,,	40022·3
2497·36	1		,,	,,	40030·6
2497·07	1	2497·15 ,,	,,	,,	40035·3
2496·61	2	2496·60 ,,	,,	,,	40042·6
2495·91	3	2496·01 ,,	,,	,,	40053·8
2494·12	2n	2494·10 ,,	,,	11·8	40082·5
2493·31	8	2493·34 ,,	,,	,,	40095·5
2492·41	3	2492·72 ,,	,,	,,	40110·0
2492·05	1	2492·12 ,,	,,	,,	40115·8
2491·47	4	2491·50 ,,	,,	,,	40125·1
2491·22	2		,,	,,	40129·2
2490·91	3	2490·98 ,,	,,	,,	40134·2
2490·75	3	2490·50 ,,	,,	,,	40136·7
2489·92	5	2490·01 ,,	,,	,,	40150·1
2489·52	3	2489·63 ,,	,,	,,	40156·5
2489·00	1	2489·04 ,,	,,	,,	40164·9
2488·40	1n		,,	,,	40174·6
2488·23	2n	2488·23 ,,	,,	,,	40177·3
2487·43	1	2487·44 ,,	,,	,,	40190·3
2487·12	1	2487·18 ,,	,,	,,	40195·3
2486·76	1	2486·77 ,,	,,	,,	40201·2
2486·39	5	2486·42 ,,	,,	,,	40207·1
2485·15	1	2485·21 ,,	,,	,,	40227·2
2484·63	2		,,	,,	40235·6

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2484·30	3	2484·35 K. & R.	0·80	11·8	40241·0
2483·83	2		,,	,,	40248·6
2483·33	4n	2483·34 ,,	,,	,,	40256·7
2482·78	4		,,	,,	40265·6
2482·38	2		,,	,,	40272·1
2482·18	4	2482·16 ,,	,,	,,	40265·4
2481·66	2		,,	,,	40283·8
2481·11	3	2481·11 ,,	,,	,,	40292·7
2480·22	5	2480·25 ,,	,,	,,	40307·2
2479·83	3	2479·64 ,,	,,	,,	40313·6
2479·53	1		,,	,,	40318·4
2479·29	1		,,	,,	40312·4
2478·62	4	2478·67 ,,	,,	,,	40333·1
2478·20	2	2478·22 ,,	,,	,,	40340·1
2477·40	3	2477·41 ,,	,,	,,	40353·1
2476·74	2	2476·77 ,,	,,	11·9	40363·8
2476·31	2	2476·40 ,,	,,	,,	40370·8
2475·70	2n		,,	,,	40380·7
2475·25	1n		,,	,,	40388·0
2474·82	3	2474·88 ,,	,,	,,	40395·1
2473·41	3	2473·30 ,,	,,	,,	40418·1
2473·00	2n	2473·15 ,,	,,	,,	40424·8
2472·65	1n		,,	,,	40430·0
2472·45	3	2472·40 ,,	,,	,,	40433·8
2472·14	2		,,	,,	40437·7
2471·72	1		,,	,,	40445·8
2471·40	1		,,	,,	40451·0
2470·73	4	2470·78 ,,	,,	,,	40462·1
2470·44	3		,,	,,	40466·7
2469·92	1	2470·01 ,,	,,	,,	40475·2
2469·53	4	2469·53 ,,	,,	,,	40481·6
2468·95	2	2468·97 ,,	,,	,,	40491·2
2468·67	1		,,	,,	40495·7
2468·34	3	2468·41 ,,	,,	,,	40501·2
2467·80	1	2467·80 ,,	,,	,,	40510·0
2466·87	4	2466·81 ,,	,,	,,	40525·3
2466·73	4		,,	,,	40528·6
2466·00	4	2466·02 ,,	,,	,,	40539·6
2465·28	4	2465·23 ,,	,,	,,	40551·4
2464·95	4	2465·05 ,,	,,	,,	40556·9
2464·10	4	2464·09 ,,	,,	,,	40570·9
2463·79	2	2463·86 ,,	,,	,,	40576·0
2463·36	4	2463·39 ,,	,,	,,	40583·1
2462·73	2	2462·81 ,,	,,	,,	40593·4
2462·24	1	2462·30 ,,	,,	,,	40601·5
*2461·90	5	2461·89 ,,	,,	,,	40607·1
2461·36	5	2461·28 ,,	,,	,,	40616·0
2460·60	5n	2460·37 ,,	,,	,,	40628·6
2459·50	1	2459·53 ,,	,,	12·0	40646·7
2458·98	3		,,	,,	40655·3
2458·80	6	2458·78 ,,	,,	,,	40658·2
2457·64	$2b^{v}$	2457·68 ,,	,,	,,	40677·4
2456·40	2	2456·67 ,,	,,	,,	40681·4
2456·18	2	2456·14 ,,	,,	,,	40685·1
2456·98	2b	2455·66 ,,	,,	,,	40704·9

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2454·63	4	2454·55 K. & R.	0·80	12·0	40727·3
2454·2	2b		,,	,,	40734·5
2453·85	2	2453·57 ,,	,,	,,	40740·3
2453·56	1		,,	,,	40745·1
2452·98	1n	2452·67 ,,	,,	,,	40754·7
2451·40	1	2451·55 ,,	,,	,,	40781·0
2451·29	2	2451·28 ,,	,,	,,	40782·8
2451·20	1		,,	,,	40784·3
2450·28	3		,,	,,	40799·6
2450·00	3		,,	,,	40804·3
2449·87	1	2449·93 ,,	,,	,,	40806·5
2449·37	1		,,	,,	40814·8
2449·28	1		,,	,,	40816·3
2448·80	1	2448·88 ,,	,,	,,	40824·3
(2447·79)	4	2447·81 ,,	,,	,,	40841·2
*2447·31	4	2447·25 ,,	,,	,,	40849·2
2446·50	4	2446·53 ,,	,,	,,	40862·7
2446·15	3	2446·30 ,,	,,	,,	40868·6
2445·88	2		,,	,,	40873·1
2445·67	4	2445·68 ,,	,,	,,	40876·6
2445·21	2	2445·23 ,,	,,	,,	40884·3
2444·57	6	2444·58 ,,	,,	,,	40894·9
2443·90	2	2443·94 ,,	,,	12·1	40906·1
2442·62	3	2442·68 ,,	,,	,,	40927·5
2442·18	1		,,	,,	40934·9
2441·62	1	2441·73 ,,	,,	,,	40944·0
2441·23	1		,,	,,	40950·8
2440·48	4	2440·25 ,,	,,	,,	40963·5
2440·16	1		,,	,,	40968·8
2439·79	2	2439·82 ,,	,,	,,	40975·0
2439.35	6	2439·36 ,,	,,	,,	40982·4
2438·22	1	2438·27 ,,	,,	,,	41001·4
2437·75	1		,,	,,	41009·3
2437·22	3	2437·33 ,,	,,	,,	41018·2
2436·70	3		,,	,,	41027·0
2436·24	2	2436·45 ,,	,,	,,	41033·7
2435·84	1	2435·93 ,,	,,	,,	41040·8
2434·98	5	2435·04 ,,	,,	,,	41056·0
2434·70	5		,,	,,	41060·7
2434·3	3b		,,	,,	41067·5
2433·55	5	2433·54 ,,	,,	,,	41080·1
2432·92	6	2432·97 ,,	,,	,,	41090·8
2432·30	6	2432·34 ,,	,,	,,	41100·9
2431·35	1b	2431·38 ,,	,,	,,	41117·3
2431·02	1	2431·08 ,,	,,	,,	41122·9
2430·90	1		,,	,,	41124·9
2430·18	7	2430·16 ,,	,,	,,	41137·1
2429·95	1		,,	,,	41141·0
2429·45	3	2429·53 ,,	,,	,,	41149·5
2429·08	2	2429·00 ,,	,,	,,	41155·7
2428·80	2		,,	,,	41160·4
2428·41	6	2428·41 ,,	,,	,,	41187·1
2427·32	3b	2427·11 ,,	,,	12·2	41185·5
2426·67	1n	2426·46 ,,	,,	,,	41196·5
2425·97	2		,,	,,	41208·4

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2425·73	3	2425·68 K. & R.	0·80	12·2	41212·5
2425·41	2		,,	,,	41217·9
2424·70	4		,,	,,	41230·6
2424·49	2		,,	,,	41233·6
2424·18	7	2424·22 ,,	,,	,,	41238·7
2423·28	5	2423·25 ,,	,,	,,	41254·2
2423·00	1		,,	,,	41259·0
2422·75	5	2422·73 ,,	,,	,,	41263·2
2421·98	1		,,	,,	41276·3
2421·82	1n	2421·79 ,,	,,	,,	41279·1
2421·0	1b	2421·02 ,,	,,	,,	41293·0
2420·1	2b	2420·39 ,,	,,	,,	41308·4
2419·42	1	2419·49 ,,	,,	,,	41320·0
2418·7	2n		,,	,,	41332·3
2418·6	2n		,,	,,	41334·0
2417·91	5	2417·94 ,,	,,	,,	41345·8
2416·75	3	2416·68 ,,	,,	,,	41365·7
2416·54	3		,,	,,	41369·3
2415·85	1n	2416·00 ,,	,,	,,	41381·1
2415·49	1	2415·29 ,,	,,	,,	41387·3
2415·12	3		,,	,,	41393·6
2414·16	2		,,	,,	41410·0
2413·36	8	2413·37 ,,	,,	,,	41423·8
2412·57	1n	2412·45 ,,	,,	12·3	41437·2
2411·95	1n		,,	,,	41447·9
2411·72	1	2411·79 ,,	,,	,,	41451·9
2411·15	7	2411·16 ,,	,,	,,	41461·7
2410·59	8	2410·56 ,,	,,	,,	41471·6
2409·78	1		,,	,,	41485·3
2409·43	1		,,	,,	41491·3
2408·80	2n		,,	,,	41502·1
2408·00	2	2408·13 ,,	,,	,,	41515·9
2407·08	2		,,	,,	41531·8
2406·73	6	2406·72 ,,	,,	,,	41537·9
2406·18	1		,,	,,	41547·4
2405·89	1		,,	,,	41552·4
2405·82	1	2405·02 ,,	,,	,,	41553·6
2404·98	7	2404·48 ,,	,,	,,	41568·1
2404·49	4		,,	,,	41576·6
2403·92	1	2402·67 ,,	,,	,,	41586·4
2402·70	3		,,	,,	41607·5
2402·37	1	2402·23 ,,	,,	,,	41613·2
2402·14	2	2401·60 ,,	,,	,,	41617·2
2401·45	2n	2401·25 ,,	,,	,,	41629·2
2400·40	4	2400·39 ,,	,,	,,	41647·4
2399·31	8	2399·31 ,,	,,	,,	41666·3
2398·77	2n		,,	,,	41675·7
2398·05	1n	2398·29 ,,	,,	12·4	41688·2
2396·80	3		,,	,,	41709·9
2395·73	7	2395·62 ,,	,,	,,	41728·5
2395·51	4		,,	,,	41732·4
2394·98	3		,,	,,	41741·6
2394·20	1b	2394·33 ,,	,,	,,	41755·2
2393·35	1b		,,	,,	41770·1
2393·13	1		,,	,,	41773·9

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
2392·75	1n	2392·70 K. & R.	0·80	12·4	41780·5
2392·27	1n		,,	,,	41788·9
2391·59	4	2391·53 ,,	,,	,,	41800·1
2391·10	1n		,,	,,	41809·4
2390·92	1n		,,	,,	41812·5
2390·31	1n		,,	,,	41823·2
2390·04	1n	2390·03 ,,	,,	,,	41827·9
2389·51	1		,,	,,	41837·2
2388·71	7	2388·71 ,, ·710 R.	,,	,,	41851·2
2388·46	2	2388·42 ,,	,,	,,	41855·1
2388·28	2		,,	,,	41859·7
2387·51	3		,,	,,	41872·2
2386·53	2b		,,	,,	41889·4
2385·10	2	2385·07 ,,	,,	,,	41914·6
2384·49	5	2384·48 ,,	,,	,,	41925·3
2383·40	4		,,	,,	41944·5
2383·17	2	2383·24 ,,	,,	12·5	41948·5
2383·00	2		,,	,,	41951·4
2382·13	9	2382·15 ,, ·122 R.	,,	,,	41966·7
2380·86	5	2380·82 ,,	,,	,,	41989·1
2380·35	1		,,	,,	41998·1
2379·36	7	2379·38 ,,	,,	,,	42015·6
2379·05	1		,,	,,	42021·1
2378·57	2		,,	,,	42029·6
2377·63	1		,,	,,	42046·2
2376·60	6n	2376·54 ,,	,,	,,	42064·4
2375·30	6	2375·30 ,,	,,	,,	42087·4
2374·61	1	2374·59 ,,	,,	,,	42099·7
2373·82	8	2373·79 ,, ·771 R.	,,	,,	42013·7
2372·73	4	2372·65 ,,	,,	,,	42133·3
2372·50	1n		,,	,,	42137·1
2371·90	1b		,,	,,	42147·8
2371·52	1	2371·51 ,,	,,	,,	42154·6
2371·07	1n		,,	,,	42162·6
2370·60	3	2370·56 ,,	,,	,,	42170·9
2370·17	5n		,,	,,	42178·6
2369·33	1	2369·55 ,,	,,	,,	42193·5
2368·69	8	2368·66 ,,	,,	12·6	42206·4
2367·00	1		,,	,,	42235·0
2366·69	3	2366·66 ,,	,,	,,	42244·1
2365·92	2n	2365·61 ,,	,,	,,	42254·2
(2364·90)	7	2364·88 ,, ·897 R.	,,	,,	42272·5
2364·00	3n	2363·81 ,,	,,	,,	42288·6
2363·68	1n		,,	,,	42294·3
2362·23	4	2362·11 ,,	,,	,,	42320·3
2361·83	3		,,	,,	42327·4
2360·42	5	2360·37 ,,	,,	,,	42352·8
2360·08	5	2360·06 ,,	,,	,,	42358·8
2359·68	2		,,	,,	42366·0
2359·23	7	2359·16 ,,	,,	,,	42375·1
2358·43	1		,,	,,	42388·5
2357·10	3		,,	,,	42412·4
2356·55	1		,,	,,	42422·3
2355·50	2b	2355·37 ,,	,,	,,	42440·2
2355·29	2		,,	,,	42445·0

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2355·00	5	2354·93 K. & R.	0·80	12·6	42450·2
2354·59	5		,,	12·7	42460·7
2353·75	2b		,,	,,	42472·6
*2352·50	2n		,,	,,	42495·3
2352·12	1		,,	,,	42502·1
2351·84	1		,,	,,	42507·4
2351·31	6	2351·22 ,,	,,	,,	42516·8
2350·72	1n	2350·50 ,,	,,	,,	42526·5
2350·33	1n		,,	,,	42534·6
2349·45	1n		,,	,,	42550·4
2348·40	7	2348·28 ,, ·385 R.	,,	,,	42569·5
2348·23	7		,,	,,	42570·5
2346·80	1n		,,	,,	42598·5
2346·37	1n		,,	,,	42611·1
2346·0	1n		,,	,,	42613·0
2345·43	6	2345·29 ,,	,,	,,	42623·4
2344·40	5	2344·37 ,,	,,	,,	42642·1
2344·05	3		,,	,,	42648·5
2343·58	9	2343·52 ,, ·57 R.	,,	,,	42657·1
2342·36	1		,,	,,	42679·3
2342·07	1		,,	,,	42684·6
2341·33	1		,,	,,	42698·0
2341·04	1		,,	,,	42703·3
2340·55	2n	2340·30 ,,	,,	12·8	42712·2
2339·50	3		,,	,,	42731·3
2339·05	1		,,	,,	42739·6
2338·09	8	2338·08 ,,	,,	,,	42757·2
2337·65	1		,,	,,	42765·0
2336·97	2n		,,	,,	42777·6
2335·55	2n		,,	,,	42802·9
2335·25	1		,,	,,	42808·4
2334·5	1b	2334·83 ,,	,,	,,	42822·9
2333·84	1		,,	,,	42835·0
2332·88	8	2332·87 ,,	,,	,,	42852·7
2332·62	1		,,	,,	42857·5
2331·41	7	2331·38 ,,	,,	,,	42879·7
2331·18	1		,,	,,	42883·9
2330·60	1n		,,	,,	42894·6
2330·17	1n		,,	,,	42902·5
2329·44	2	2329·67 ,,	,,	,,	42916·0
2328·03	2		,,	,,	42944·0
2327·49	6	2327·40 ,,	,,	12·9	42951·8
2326·95	1n		,,	,,	42961·8
2326·43	2		,,	,,	42971·4
2325·80	1b		,,	,,	42983·0
2325·65	2		,,	,,	42985·8
2325·38	2		,,	,,	42990·8
2324·60	1n		,,	,,	43005·3
2323·2	1b		,,	,,	43033·0
2322·43	1		,,	,,	43045·6
2321·76	2		,,	,,	43058·2
2320·44	2	2320·42 ,,	,,	,,	43082·4
2318·62	2		,,	,,	43118·1
2318·41	1	2318·23 ,,	,,	,,	43120·1
2317·40	2n	2317·32 ,,	,,	,,	43138·9

* Double.

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2315·9	1b		0·80	12·9	43166·9
2314·90	1b		,,	,,	43184·5
2314·05	1	2314·10 K. & R.	,,	13·0	43201·3
2313·38	1		,,	,,	43213·8
2313·17	1	2313·17 ,,	,,	,,	43217·7
2312·10	2	2312·40 ,,	,,	,,	43237·7
2311·33	3		,,	,,	43252·1
2310·17	1		,,	,,	43273·8
2309·04	2	2309·04 ,,	,,	,,	43395·0
2308·80	2		,,	,,	43399·5
2307·75	1		,,	,,	43319·2
2307·37	3		,,	,,	43323·4
2306·45	1	2306·35 ,,	,,	,,	43343·7
2306·06	1		,,	,,	43351·0
2304·78	2	2304·82 ,,	,,	,,	43375·1
2303·87	1		,,	,,	43393·2
2303·63	1		,,	,,	43396·7
2303·42	2	2303·52 ,,	,,	,,	43400·7
2301·74	1	2301·75 ,,	,,	,,	43432·4
2301·50	1		,,	,,	43436·9
2301·20	1n		,,	13·1	43442·5
2300·48	1n		,,	,,	43456·1
2300·19	1	2300·20 ,,	,,	,,	43461·6
2299·27	1	2299·30 ,,	,,	,,	43478·6
2298·68	1		,,	,,	43590·1
(2298·25)	2	2298·24 ,,	,,	,,	43598·3
2297·76	1	2297·85 ,,	,,	,,	43507·5
2296·96	1	2297·04 ,,	,,	,,	43522·7
2296·87	1		,,	,,	43524·4
2296·72	1		,,	,,	43527·2
2296·3	1b	2296·23 ,,	,,	,,	43535·2
2295·8	1b		,,	,,	43544·7
2294·68	2		,,	,,	43559·9
2294·48	1	2294·45 ,,	,,	,,	43569·7
2293·89	2	2293·90 ,,	,,	,,	43581·0
2293·20	1		,,	,,	43594·1
2292·90	1		,,	,,	43599·8
2292·57	1	2292·56 ,,	,,	,,	43606·1
2291·69	1		,,	,,	43622·8
2291·21	1	2291·18 ,,	,,	,,	43632·0
2290·60	1	2290·61 ,,	,,	,,	43643·6
2288·8	1b		,,	,,	43677·9
2287·65	1n	2287·70 ,,	,,	13·2	43699·8
2287·31	1	2287·37 ,,	,,	,,	43706·3
2284·10	3	2284·12 ,,	,,	,,	43767·7
2283·74	1		,,	,,	43774·6
2283·37	1	2283·15 ,,	,,	,,	43781·7
2279·98	4	2280·05 ,,	,,	,,	43846·8
2276·07	2	2276·07 ,,	,,	,,	43922·2
2274·13	1	2274·09 ,,	,,	13·3	43959·6
2272·13	1		,,	,,	43998·2
2271·87	1	2271·84 ,,	,,	,,	44003·3
2270·40	1	2270·47 ,,	,,	,,	44031·8
2268·91	1	2268·96 ,,	,,	,,	44056·7
2268·58	1		,,	,,	44067·1

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ −	
2268·20	1		0·80	13·3	44074·6
2267·64	3	2267·51 K. & R.	,,	,,	44085·4
2267·14	1		,,	,,	44095·1
2266·77	1		,,	,,	44102·4
2266·32	1	2266·37 ,,	,,	,,	44111·1
2266·05	1		,,	,,	44116·4
2264·65	2	2264·51 ,,	,,	,,	44143·6
2264·42	1		,,	,,	44148·1
2263·30	2	2263·37 ,,	,,	13·4	44169·9
2262·75	2		,,	,,	44180·6
2262·36	1		,,	,,	44188·2
2260·92	2	2260·83 ,,	,,	,,	44216·4
2260·20	1n		,,	,,	44230·5
2260·13	2	2260·15 ,,	,,	,,	44230·8
2259·62	1	2259·50 ,,	,,	,,	44241·8
2257·90	2		,,	,,	44275·4
2257·00	1n		,,	,,	44293·2
2256·49	1		,,	,,	44303·2
2255·82	3	2255·94 ,,	,,	,,	44316·4
2255·24	1		,,	,,	44327·8
2254·42	1		,,	,,	44343·9
2254·25	1		,,	,,	44347·3
2254·14	1		,,	,,	44349·4
2253·18	2	2253·15 ,,	,,	,,	44368·3
2251·97	2		,,	,,	44392·2
2251·62	1	2251·6 L. & D.	,,	13·5	44418·7
2251·03	2	2251·2 ,,	,,	,,	44410·6
2250·24	1	2250·5 ,,	,,	,,	44426·2
2249·20	2		,,	,,	44446·7
2247·80	2n		,,	,,	44474·4
2247·00	2		,,	,,	44490·3
2245·64	2n	2245·3 ,,	,,	,,	44517·2
2244·38	2n		,,	,,	44542·2
2243·23	1b		,,	,,	44565·1
2242·68	1		,,	,,	44576·0
2242·40	1	2242·2 ,,	,,	,,	44581·6
2241·90	1		,,	,,	44591·5
2241·56	2		,,	,,	44598·3
2240·63	1		,,	,,	44616·8
2239·70	1		,,	,,	44635·3
2239·18	2		,,	,,	44645·4
2238·71	1		,,	13·6	44655·0
2238·33	1n		,,	,,	44662·6
2237·96	2		,,	,,	44670·0
2237·66	2		,,	,,	44696 5
2235 93	1		,,	,,	44710·5
2235·58	1		,,	,,	44717·5
2234·00	3		,,	,,	44749·2
2232·19	2		,,	,,	44785·4
2231·64	2		,,	,,	44896·5
2228·88	2		,,	,,	44852·0
2227·68	1		,,	,,	44876·2
2227·55	1		,,	,,	44878·8
2227·45	1	2227·3 ,,	,,	,,	44880·8
2227·23	1		,,	,,	44885·2

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2224·58	1		0·80	13·7	44938·6
2223·56	2		,,	,,	44980·1
2222·53	1		,,	,,	44959·3
2221·25	2		,,	,,	44996·0
2220·48	3		,,	,,	45021·6
2219·97	2		,,	,,	45032·0
2218·90	2		,,	,,	45053·7
2217·15	1		,,	,,	45189·2
2215·88	1n		,,	,,	45115·0
2215·22	1n		,,	13·8	45128·5
2214·20	1n	2214·1 L. & D.	,,	,,	45149·2
2213·74	3		,,	,,	45158·6
2211·19	1		,,	,,	45210·7
2209·78	1		,,	,,	45239·6
2209·18	2		,,	,,	45251·9
2208·54	2		,,	,,	45265·0
2206·68	1		,,	,,	45303·1
2206·30	2n		,,	,,	45310·9
2201·72	1n		,,	13·9	45486·1
2200·81	1		,,	,,	45423·9
2200·44	1	2200 2 ,,	,,	,,	45431·6
2198·86	1n		,,	,,	45464·2
2196·14	1		,,	,,	45520·5
2192·30	1		,,	14·0	45600·2
2192·08	1		,,	,,	45604·8
2191·94	1		,,	,,	45607·7
2189·12	1		,,	,,	45666·5
2187·82	1		,,	,,	45793·7
2187·40	1		,,	,,	45702·4
2187·28	1		,,	,,	45704·9
2186·92	1	2286·8 ,,	,,	,,	45712·6
2186·56	1		,,	,,	45719·9
2183·85	1	2283·7 ,,	,,	,,	45776·7
2180·55	1		,,	14·1	45845·8
2178·15	1	2278·0 ,,	,,	,,	45996·4
2177·10	1	2177·0 ,,	,,	,,	45918·6
2176·68	1		,,	,,	45927·4
2175·54	2		,,	,,	45951·5
2174·95	1		,,	,,	45963·9
2174·77	1		,,	,,	45967·8
2173·07	1		,,	,,	46003·8
2167·90	1		,,	14·2	46113·4
2167·50	1	2167·4 ,,	,,	,,	46121·9
2166·81	2		,,	,,	46136·6
2164·40	1		,,	,,	46188·0
2162·08	2		,,	,,	46237·6
2161·18	1		,,	,,	46256·8
2152·42	1		,,	14·3	46445·0
2151·9	1n		,,	,,	46455·9
2151·15	1		,,	,,	46472·5
2150·67	1		,,	,,	46482·9
2147·74	1		,,	14·4	46546·2
2146·06	1		,,	,,	46531·6
2136·50	1		,,	14·5	46791·0
2136·00	1		,,	,,	46812·0

IRON—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
2097·60	1		0·80	14·8	47658·7
2097·48	1		,,	,,	47661·4
2087·54	1		,,	14·9	47888·4
2079·00	1		,,	15·0	48085·0
2068·25	1n		,,	15·1	48334·9

TUNGSTEN (SPARK SPECTRUM).

Exner and Haschek: 'Sitzber. k. Akad. W. Wien,' civ. (1895), cv. (1896), cvi. (1897).

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
4844·7	1		1·33	5·7	20635
4694·1	2n		1·29	5·9	21297
4692·0	2n		1·28	,,	21307
4687·9	1		,,	,,	21326
4683·7	2		,,	,,	21345
4682·8	1		,,	,,	21349
4681·4	1		,,	,,	21355
4680·8	6	4680·6 Thalén	,,	,,	21358
4679·8	1		,,	,,	21362
4679·3	1		,,	,,	21365
4678·8	1		,,	,,	21367
4677·9	1		,,	,,	21371
4676·9	1		,,	,,	21376
4675·4	1n		,,	,,	21383
4675·2	1n		,,	,,	21383
4672·4	1		,,	,,	21396
4671·9	1		,,	,,	21399
4671·6	1		,,	,,	21400
4668·7	1		,,	,,	21413
4666·0	2		,,	,,	21425
4665·0	1n		,,	,,	21430
4664·1	1n		,,	,,	21434
4663·2	1n		,,	,,	21438
4662·1	1		,,	,,	21444
4661·7	1		,,	,,	21445
4661·4	1		,,	,,	21447
4660·0	6	4660·6 ,,	,,	,,	21453
4658·3	1	4659·6 ,,	,,	,,	21461
4657·6	4		,,	,,	21464
4655·5	1n		,,	,,	21474
4654·4	1n		1·27	,,	21479
4650·9	2n		,,	,,	21495
4646·3	1		,,	,,	21517
4645·3	1		,,	,,	21521
4645·1	1		,,	,,	21522
4642·7	2		,,	,,	21533
4640·4	1		,,	,,	21544

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4638·0	1n		1·27	5·9	21555
4637·4	1n		"	"	21558
4636·2	1		"	"	21563
4634·8	2		"	6·0	21570
4633·3	1n		"	"	21577
4632·7	1n		"	"	21580
4631·8	1n		"	"	21584
4629·9	1		"	"	21593
4629·5	1		"	"	21595
4629·0	1		"	"	21597
4628·6	1		"	"	21599
4627·8	1n		"	"	21603
4627·4	1n		"	"	21604
4627·1	1n		"	"	21606
4626·3	1n		"	"	21611
4625·4	1n		"	"	21614
4623·9	1n		"	"	21621
4623·5	1		"	"	21623
4620·8	1		"	"	21635
4616·6	1n		1·26	"	21655
4615·0	1		"	"	21662
4613·50	4		"	"	21669·5
4610·0	2		"	"	21686
4609·0	1n		"	"	21691
4606·6	1		"	"	21704
4604·8	2		"	"	21710
4603·5	1b		1·26	6·0	21717
4601·6	1b		"	"	21726
4601·0	1		"	"	21728
4600·6	1		"	"	21730
4600·1	2		"	"	21733
4598·4	1		"	"	21741
4592·60	4		"	"	21768·2
4588·92	4		"	"	21785·6
4587·8	1n		"	"	21791
4586·9	2		"	"	21795
4586·1	1		"	"	21799
4585·5	1n		"	"	21802
4584·8	1n		"	"	21805
4582·2	1		"	"	21818
4579·8	1n		1·25	"	21829
4578·3	2		"	"	21836
4575·2	1n		"	"	21851
4572·8	1		"	"	21862
4572·6	1		"	"	21863
4571·9	1		"	"	21871
4570·80	4		"	"	21872·0
4569·3	1n		"	"	21879
4567·6	1n		"	"	21887
4567·3	1n		"	"	21889
4566·3	1		"	"	21894
4565·4	1		"	"	21898
4564·1	1		"	6·1	21904
4563·7	1		"	"	21906
4562·1	1		"	"	21914

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
4561·6	1		1·25	6·1	21916
4560·4	1		"	"	21922
4559·0	1		"	"	21929
4556·8	1		"	"	21939
4555·3	1n		"	"	21946
4554·22	8		"	"	21951·6
4552·6	1		"	"	21959
4551·9	2		"	"	21963
4550·4	1		"	"	21970
4549·8	1n		"	"	21973
4546·5	1		"	"	21989
4545·6	1n		"	"	21993
4544·6	1n		"	"	21998
4543·6	2		"	"	22003
4542·9	1		1·24	"	22006
4542·0	1		"	"	22011
4540·3	1		"	"	22019
4539·8	1		"	"	22021
4536·6	2		"	"	22037
4535·0	2		"	"	22045
4534·6	2		"	"	22047
4532·3	1		"	"	22058
4530·5	1		"	"	22067
4529·8	1		"	"	22070
4528·6	1n		"	"	22076
4527·3	1		"	"	22082
4522·9	1n		"	"	22104
4520·0	1n		"	"	22118
4519·1	1		"	"	22122
4517·4	1		"	"	22131
4516·5	1n		"	"	22135
4515·8	1n		"	"	22138
4514·1	1n		"	"	22147
4513·1	2		"	"	22152
4512·8	2		"	"	22153
4511·0	1		"	"	22162
4509·6	1		"	"	22169
4509·3	1		"	"	22170
4508·9	1		"	"	22172
4508·4	1		"	"	22175
4504·8	2		1·23	"	22193
4504·0	2		"	"	22196
4503·1	1		"	"	22201
4502·3	1		"	"	22205
4500·3	1		"	"	22215
4500·2	1		"	"	22215
4498·6	2		"	"	22223
4497·8	1		"	"	22227
4497·0	1		"	6·2	22231
4496·4	1n		"	"	22234
4495·4	1		"	"	22239
4494·7	1		"	"	22242
4494·0	2		"	"	22246
4492·4	1		"	"	22254
4490·0	1		"	"	22266

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
4489·1	2		1·23	6·2	22270
4488·5	1		,,	,,	22273
4487·8	1		,,	,,	22277
4487·5	1n		,,	,,	22278
4485·3	1		,,	,,	22289
4484·33	6		,,	,,	22293·7
4482·0	1		,,	,,	22305
4481·5	2		,,	,,	22308
4480·3	1		,,	,,	22314
4479·0	1		,,	,,	22320
4478·6	1		,,	,,	22321
4476·0	1		,,	,,	22335
4475·7	1		,,	,,	22337
4475·0	1n Mo		,,	,,	22340
4474·1	2		,,	,,	22345
4473·0	1		,,	,,	22350
4472·6	1		,,	,,	22352
4472·0	1		,,	,,	22355
4471·6	1		,,	,,	22357
4469·9	1		,,	,,	22366
4468·8	2		1·22	,,	22371
4466·9	2		,,	,,	22381
4466·5	2		,,	,,	22383
4465·8	1		,,	,,	22386
4463·5	1		,,	,,	22398
4463·1	1		,,	,,	22400
4462·6	1		,,	,,	22402
4460·6	2		,,	,,	22413
4459·3	1b		,,	,,	22419
4458·4	1		,,	,,	22424
4458·2	1		,,	,,	22425
4456·2	1		,,	,,	22435
4454·9	1		,,	,,	22441
4452·3	1		,,	,,	22454
4450·4	1		,,	,,	22464
4449·9	1		,,	,,	22466
4449·0	2		,,	,,	22471
4445·2	2		,,	,,	22490
4444·6	1		,,	,,	22493
4444·2	1		,,	,,	22495
4443·1	1		,,	,,	22501
4442·8	1		,,	,,	22502
4442·5	1		,,	,,	22504
4441·9	2		,,	,,	22507
4439·8	1		,,	,,	22518
4439·0	2		,,	,,	22522
4438·5	1		,,	,,	22524
4437·6	1		,,	,,	22529
4437·0	2		,,	,,	22532
4435·8	1		,,	,,	22538
4435·1	1 Mo		,,	,,	22541
4433·7	1n		,,	,,	22549
4433·1	1		,,	,,	22552
4432·2	1		1·21	,,	22556
4430·9	1n		,,	6·3	22563

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
4429·0	1		1·21	6·3	22572
4428·6	1		,,	,,	22574
4427·6	1n		,,	,,	22580
4425·6	1		,,	,,	22590
4425·1	1		,,	,,	22592
4423·8	2		,,	,,	22599
4422·8	1n		,,	,,	22604
4422·5	1		,,	,,	22605
4421·9	2		,,	,,	22609
4421·1	1		,,	,,	22613
4420·6	2		,,	,,	22615
4419·4	1		,,	,,	22622
4418·9	1		,,	,,	22624
4418·6	1		,,	,,	22626
4415·8	1		,,	,,	22640
4413·4	1		,,	,,	22652
4413·2	1		,,	,,	22653
4412·4	1 Mo		,,	,,	22657
4411·5	1		,,	,,	22662
4411·1	1		,,	,,	22664
4410·0	1		,,	,,	22670
4409·6	1n		,,	,,	22672
4408·8	1		,,	,,	22676
4408·42	4		,,	,,	22677·6
4406·1	2		,,	,,	22690
4404·8	1		,,	,,	22697
4403·5	1		,,	,,	22703
4402·8	1		,,	,,	22707
4400·3	1n		,,	,,	22720
4396·9	1		,,	,,	22737
4395·1	1		,,	,,	22747
4394·5	1		,,	,,	22750
4393·8	2		1·20	,,	22753
4390·9	1		,,	,,	22768
4389·9	2		,,	,,	22774
4387·9	1n		,,	,,	22784
4387·5	1		,,	,,	22786
4386·7	1		,,	,,	22790
4385·01	4		,,	,,	22798·7
4383·6	4		,,	,,	22806
4381·8	1n		,,	,,	22816
4380·1	1		,,	,,	22825
4379·3	1		,,	,,	22829
4378·72	4		,,	,,	22831·4
4377·5	1n		,,	,,	22838
4373·8	1n		,,	,,	22857
4373·0	1n		,,	,,	22862
4372·5	2		,,	,,	22864
4371·8	1		,,	,,	22868
4370·8	1		,,	,,	22873
4368·7	1		,,	,,	22884
4366·20	4		,,	6·4	22886·3
4364·90	4		,,	,,	22903·6
4361·6	2		,,	,,	22921
4361·1	1		,,	,,	22924

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ−	
4360·0	1n		1·20	6·4	22930
4359·3	1n		,,	,,	22933
4358·6	1n		,,	,,	22937
4358·0	1n		,,	,,	22940
4356·5	1n		1·19	,,	22948
4355·2	2		,,	,,	22955
4354·2	2		,,	,,	22960
4348·23	6		,,	,,	22991·5
4347·0	2		,,	,,	22998
4346·3	1		,,	,,	23002
4345·9	1		,,	,,	23004
4345·1	1		,,	,,	23008
4343·2	2		,,	,,	23018
4342·4	1		,,	,,	23023
4341·3	1n		,,	,,	23029
4339·5	1		,,	,,	23038
4339·1	1		,,	,,	23040
4338·6	1		,,	,,	23043
4338·2	1n		,,	,,	23045
4335·70	4		,,	,,	23057·9
4332·0	4		,,	,,	23078
4330·7	2		,,	,,	23085
4326·9	1n		,,	,,	23105
4325·1	1n		,,	,,	23115
4324·6	1		,,	,,	23118
4322·9	1		,,	,,	23127
4321·5	1n		,,	,,	23134
4320·4	1n		,,	,,	23140
4318·6	1		1·18	,,	23150
4316·8	2		,,	,,	23159
4316·3	1n		,,	,,	23162
4315·3	1n		,,	,,	23167
4313·1	1n		,,	,,	23179
4312·8	1n		,,	,,	23181
4312·3	1		,,	,,	23183
4311·0	1n		,,	,,	23190
4310·2	1		,,	,,	23195
4310·0	1		,,	,,	23196
4309·3	1		,,	,,	23200
4309·0	1		,,	,,	23201
4308·0	6Fe		,,	6·5	23207
4307·00	4		,,	,,	23211·5
4306·3	1		,,	,,	23216
4305·8	1		,,	,,	23218
4305·6	1		,,	,,	23220
4305·1	1n		,,	,,	23222
4303·4	4		,,	,,	23231
4302·6	1		,,	,,	23236
4302·27	6	4302·0 Thalén	,,	,,	23237·0
4301·1	1		,,	,,	23244
4299·0	1n		,,	,,	23255
4297·6	1n		,,	,,	23263
4297·2	1n		,,	,,	23265
4295·7	1n		,,	,,	23273
4294·77	8	4295·0 ,,	,,	,,	23277·6

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4294·1	2		1·18	6·5	23282
4293·0	1n		„	„	23288
4292·8	1n		„	„	23289
4292·0	1n		„	„	23293
4291·5	1n		„	„	23296
4290·1	1		„	„	23303
4289·3	1		„	„	23308
4288·4	1		„	„	23313
4287·0	1n		„	„	23320
4286·0	2		„	„	23326
4285·0	2		„	„	23331
4283·8	1		„	„	23338
4283·0	1n		„	„	23342
4282·0	1		„	„	23348
4281·4	1n		„	„	23351
4280·5	1n		1·17	„	23356
4279·0	1		„	„	23364
4278·5	1		„	„	23367
4277·8	1		1·17	6·5	23371
4277·4	1		„	„	23373
4276·92	4 Mo		„	„	23374·8
4276·0	1		„	„	23380
4275·65	4		„	„	23381·8
4275·0	1		„	„	23386
4274·70	4		„	„	23387·0
4273·7	2		„	„	23393
4272·3	1		„	„	23401
4271·8	1		„	„	23403
4270·9	1		„	„	23408
4270·8	1		„	„	23409
4269·9	2		„	„	23414
4269·52	6	4269·0 Thalén	„	„	23415·3
4268·8	1		„	„	23420
4268·1	1		„	„	23424
4267·9	1		„	„	23425
4266·6	2		„	„	23432
4265·0	1		„	„	23441
4263·50	4		„	„	23448·4
4262·4	1		„	„	23455
4260·42	4		„	„	23465·4
4259·9	1		„	„	23469
4259·52	4		„	„	23470·3
4258·5	1		„	„	23476
4257·3	1		„	„	23483
4257·0	1		„	„	23485
4255·6	1		„	„	23492
4254·3	2		„	„	23500
4254·1	1		„	„	23501
4252·6	1n		„	6·6	23508
4251·8	1n		„	„	23512
4250·8	1		„	„	23518
4250·1	1n		„	„	23522
4249·5	1		„	„	23525
4248·8	1		„	„	23529
4248·2	1		„	„	23532

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
4247·6	1		1·17	6·6	23536
4247·3	1		,,	,,	23537
4246·0	1		,,	,,	23545
4245·6	1		,,	,,	23547
4244·45	4		,,	,,	23553·6
4243·8	1		1·16	,,	23557
4243·4	1		,,	,,	23549
4241·50	4		,,	,,	23570·0
4241·0	1		,,	,,	23572
4240·8	1		,,	,,	23573
4240·4	1		,,	,,	23576
4240·1	1		,,	,,	23577
4238·6	1		,,	,,	23586
4236·6	1		,,	,,	23597
4235·5	1		,,	,,	23603
4234·4	2		,,	,,	23609
4233·0	1		,,	,,	23617
4232·6	1		,,	,,	23619
4231·9	1		,,	,,	23623
4231·8	1		,,	,,	23624
4231·4	1		,,	,,	23626
4231·3	1		,,	,,	23626
4230·0	1n		,,	,,	23634
4229·1	1		,,	,,	23639
4228·5	1		,,	,,	23642
4227·6	1		,,	,,	23647
4226·8	6Ca		,,	,,	23652
4226·4	1		,,	,,	23654
4225·7	1		,,	,,	23658
4225·0	2		,,	,,	23662
4224·9	2		,,	,,	23662
4224·1	1n		,,	,,	23667
4222·2	2		,,	,,	23677
4222·0	1		,,	,,	23678
4221·5	1		,,	,,	23681
4220·7	1		,,	,,	23686
4220·5	1		,,	,,	23687
4219·50	4		,,	,,	23692·9
4219·2	1		,,	,,	23694
4218·7	1		,,	,,	23697
4216·0	1		,,	,,	23712
4215·60	6		,,	,,	23714·8
4215·1	1		,,	,,	23717
4214·5	1		,,	,,	23721
4214·0	1		,,	,,	23723
4213·5	1		,,	,,	23726
4212·9	1		,,	,,	23730
4211·5	1		,,	,,	23738
4210·4	1		,,	,,	23744
4210·3	1		,,	,,	23744
4209·7	1n		,,	,,	23748
4207·12	4		,,	,,	23762·6
4206·3	2		,,	,,	23767
4205·6	1n		1·15	,,	23771
4201·52	4		,,	,,	23777·3

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4203·8	2		1·15	6·6	23781
4202·0	1		,,	,,	23791
4201·3	1		,,	,,	23795
4200·9	1		,,	,,	23797
4200·5	1		,,	,,	23800
4200·1	1		,,	6·7	23802
4199·7	1		,,	,,	23804
4198·9	1		,,	,,	23809
4198·7	1		,,	,,	23810
4198·3	1		,,	,,	23812
4197·9	1		,,	,,	23814
4197·4	1		,,	,,	23817
4197·3	1		,,	,,	23818
4193·9	1n		,,	,,	23837
4193·0	1n		,,	,,	23842
4189·3	1		,,	,,	23863
4187·0	1n		,,	,,	23876
4186·0	1		,,	,,	23882
4185·5	1		,,	,,	23885
4183·7	1		,,	,,	23895
4183·6	1		,,	,,	23896
4183·0	1n		,,	,,	23899
4182·6	1		,,	,,	23902
4181·5	1		,,	,,	23908
4180·4	2		,,	,,	23914
4178·7	1		,,	,,	23924
4178·0	1n		,,	,,	23928
4177·0	1		,,	,,	23934
4176·9	1		,,	,,	23934
4176·0	1		,,	,,	23939
4175·70	4		,,	,,	23941·4
4175·2	2n		,,	,,	23944
4174·6	1n		,,	,,	23947
4172·9	1n		,,	,,	23957
4172·1	1		,,	,,	23962
4171·9	1		,,	,,	23963
4171·23	4		,,	,,	23967·0
4170·60	4		1·14	,,	23970·7
4168·80	4		,,	,,	23981·0
4168·3	1		,,	,,	23984
4166·9	1		,,	,,	23992
4166·2	1		,,	,,	23996
4165·7	1n		,,	,,	23999
4164·9	1		,,	,,	24003
4164·0	1		,,	,,	24008
4163·0	1n		,,	,,	24014
4161·6	1		,,	,,	24022
4161·0	1		,,	,,	24026
4160·4	1		,,	,,	24029
4160·0	1		,,	,,	24031
4159·0	1		,,	,,	24037
4157·1	2		,,	,,	24048
4154·8	2		,,	,,	24062
4153·2	1		,,	,,	24071
4152·6	1		,,	,,	24074

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
4151·8	1		1·14	6·7	24079
4151·1	1		"	"	24083
4150·6	1		"	"	24087
4150·0	1		"	"	24089
4149·8	1		"	"	24091
4149·5	1		"	"	24092
4149·3	1n		"	"	24093
4148·3	1		"	6·8	24099
4146·8	2		"	"	24108
4145·3	2		"	"	24117
4144·6	1		"	"	24121
4143·1	1		"	"	24130
4142·3	2		"	"	24134
4141·6	1		"	"	24138
4140·9	1		"	"	24142
4140·4	1		"	"	24145
4140·1	1		"	"	24147
4139·3	1		"	"	24152
4138·5	1		"	"	24156
4138·3	1		"	"	24158
4138·1	1		"	"	24159
4137·63	4		"	"	24161·6
4137·5	4		"	"	24162
4136·5	1		"	"	24168
4134·7	1n		"	"	24179
4133·6	2		"	"	24185
4132·3	1		"	"	24193
4130·9	1		1·13	"	24201
4130·6	1		"	"	24203
4130·2	1		"	"	24205
4127·0	1		"	"	24224
4126·9	2		"	"	24224
4125·2	1		"	"	24234
4123·0	1		"	"	24247
4122·7	1		"	"	24249
4122·0	1		"	"	24253
4120·8	1		"	"	24260
4119·0	1		"	"	24271
4118·22	4		"	"	24275·5
4114·8	1		"	"	24296
4114·2	2		"	"	24299
4113·9	1		"	"	24301
4112·4	1		"	"	24310
4111·8	2		"	"	24313
4110·6	2		"	"	24320
4109·90	4		"	"	24324·7
4108·5	1		"	"	24333
4107·9	1		"	"	24336
4106·8	1		"	"	24343
4104·0	1		"	"	24359
4102·90	6		"	"	24366·2
4101·8	1		"	"	24373
4101·0	1		"	"	24377
4099·2	2		"	6·9	24388
4097·2	1		"	"	24400

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
4096·6	1		1.13	6·9	24403
4095·8	1		,,	,,	24408
4094·3	1n		,,	,,	24417
4093·3	1		1·12	,,	24423
4092·5	1		,,	,,	24428
4091·3	1		,,	,,	24435
4091·2	1		,,	,,	24436
4090·8	1		,,	,,	24438
4090·3	1		,,	,,	24441
4089·6	1		,,	,,	24445
4088·9	2		,,	,,	24449
4088·5	2		,,	,,	24452
4087·6	1		,,	,,	24457
4087·1	1		,,	,,	24460
4084·5	1n		,,	,,	24476
4083·9	1n		,,	,,	24479
4083·1	2		,,	,,	24484
4081·45	4		,,	,,	24494·2
4081·3	1		,,	,,	24495
4079·5	1		,,	,,	24506
4079·1	1		,,	,,	24508
4078·3	1		,,	,,	24513
4077·9	2		,,	,,	24515
4075·7	1		,,	,,	24529
4074·52	6		,,	,,	24535·9
4073·2	1		,,	,,	24544
4073·1	1		,,	,,	24544
4070·7	2		,,	,,	24559
4070·03	6		,,	,,	24562·9
4067·0	1		,,	,,	24581
4065·5	1		,,	,,	24590
4065·0	2		,,	,,	24593
4063·8	1		,,	,,	24601
4060·9	1n		,,	,,	24618
4060·3	1		,,	,,	24622
4059·2	1n		,,	,,	24628
4058·0	1		,,	,,	24636
4057·5	1		,,	,,	24639
4056·8	1		,,	,,	24643
4055·8	1		,,	,,	24649
4055·2	1		,,	,,	24653
4053·5	1		1·11	,,	24663
4052·5	1		,,	,,	24669
4051·5	1		,,	,,	24675
4050·1	1n		,,	7·0	24684
4048·5	1		,,	,,	24694
4048·1	1		,,	,,	24696
4046·8	1		,,	,,	24704
4045·80	4		,,	,,	24710·0
4044·1	1		,,	,,	24720
4042·5	1		,,	,,	24730
4041·7	1		,,	,,	24735
4041·2	1		,,	,,	24738
4040·7	1		,,	,,	24741
4040·0	1		,,	,,	24745

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
4039·5	1		1·11	7·0	24749
4037·8	1		,,	,,	24759
4037·0	1		,,	,,	24764
4035·3	1		,,	,,	24774
4033·9	1		,,	,,	24783
4032·5	1n		,,	,,	24792
4031·6	1		,,	,,	24797
4031·4	1		,,	,,	24798
4030·0	1		,,	,,	24807
4029·7	1		,,	,,	24809
4029·0	1		,,	,,	24813
4028·9	1		,,	,,	24814
4028·4	1n		,,	,,	24817
4025·6	1		,,	,,	24834
4025·1	1		,,	,,	24837
4024·9	1		,,	,,	24838
4022·8	1		,,	,,	24851
4022·1	1		,,	,,	24856
4020·8	1		,,	,,	24864
4019·7	1n		,,	,,	24870
4019·3	2		,,	,,	24873
4017·0	1		,,	,,	24887
4016·2	1		,,	,,	24892
4015·32	4		1·10	,,	24897·6
4013·9	1		,,	,,	24906
4013·8	1		,,	,,	24907
4013·2	1		,,	,,	24911
4012·2	1		,,	,,	24917
4012·0	1		,,	,,	24918
4011·8	1		,,	,,	24919
4011·1	1		,,	,,	24924
4011·0	1		,,	,,	24924
4010·3	1		,,	,,	24929
4009·7	1		,,	,,	24933
4008·90	8		,,	,,	24937·5
4007·0	1		,,	,,	24949
4005·7	1		,,	,,	24957
4005·3	1		,,	,,	24960
4004·1	1		,,	,,	24967
4003·8	1		,,	7·1	24969
4002·8	1		,,	,,	24976
4001·5	1		,,	,,	24984
4000·7	1		,,	,,	24989
3998·7	1		,,	,,	25001
3998·2	1		,,	,,	25004
3997·8	1		,,	,,	25007
3997·3	1		,,	,,	25010
3997·1	1		,,	,,	25011
3995·0	1		,,	,,	25024
3993·8	1		,,	,,	25032
3992·5	1		,,	,,	25040
3991·3	1		,,	,,	25047
3990·5	1		,,	,,	25053
3988·8	1		,,	,,	25063
3988·5	1		,,	,,	25065

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3988·0	1		1·10	7·1	25068
3987·5	1		„	„	25071
3987·1	1		„	„	25074
3986·3	1n		„	„	25079
3984·9	1		„	„	25088
3984·2	1		„	„	25092
3983·40	4		„	„	25097·1
3980·7	2		„	„	25114
3980·0	1		„	„	25119
3979·3	4		„	„	25123
3977·8	1		„	„	25133
3976·5	1n		„	„	25141
3975·9	1		1·09	„	25145
3975·5	1		„	„	25147
3972·5	1		„	„	25166
3972·0	1		„	„	25169
3970·7	4		„	„	25177
3969·3	1		„	„	25186
3965·1	6		„	„	25213
3964·2	1		„	„	25219
3962·4	1		„	„	25230
3961·7	2		„	„	25235
3960·8	1		„	„	25240
3960·1	1n		„	„	25245
3959·5	1n		„	„	25249
3958·9	1		„	„	25253
3957·6	1		„	„	25261
3957·2	1		„	„	25263
3955·7	2		„	7·2	25273
3953·8	1		„	„	25285
3953·5	1		„	„	25287
3953·2	2		„	„	25289
3953·0	1		„	„	25290
3952·3	1		„	„	25295
3952·0	1		„	„	25297
3951·1	2		„	„	25302
3950·3	2		„	„	25308
3948·8	1		„	„	25317
3948·3	1		„	„	25320
3948·2	2		„	„	25321
3946·5	1		„	„	25332
3945·0	2		„	„	25342
3944·3	2		„	„	25346
3942·5	1		„	„	25358
3942·0	1		„	„	25361
3941·7	1		„	„	25363
3941·1	1		„	„	25367
3940·6	1		„	„	25370
3938·3	1		„	„	25385
3937·8	1		„	„	25388
3937·2	2		„	„	25392
3935·5	2		1·08	„	25403
3935·2	1		„	„	25405
3931·7	1		„	„	25427
3931·1	1		„	„	25431

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
3930·7	1		1·08	7·2	25434
3930·5	1		,,	,,	25435
3928·0	1		,,	,,	25451
3926·2	1		,,	,,	25463
3925·3	1		,,	,,	25469
3924·9	1		,,	,,	25471
3924·6	1		,,	,,	25473
3923·1	1		,,	,,	25483
3922·9	1		,,	,,	25494
3918·8	1		,,	,,	25511
3918·5	1		,,	,,	25513
3917·8	1		,,	,,	25518
3917·6	1		,,	,,	25519
3915·5	2n		,,	,,	25533
3914·3	1n		,,	,,	25540
3913·8	1		,,	,,	25544
3913·5	1		,,	,,	25546
3913·0	1		,,	,,	25549
3911·5	1		,,	,,	25559
3909·4	1		,,	,,	25572
3907·5	1		,,	7·3	25585
3907·3	1		,,	,,	25586
3906·1	1		,,	,,	25594
3906·0	1		,,	,,	25595
3905·8	1		,,	,,	25596
3904·2	1		,,	,,	25606
3903·5	1		,,	,,	25611
3903·1	1		,,	,,	25614
3902·0	1		,,	,,	25621
3901·5	1		,,	,,	25624
3901·0	1		,,	,,	25627
3900·0	1		,,	,,	25634
3899·0	1		,,	,,	25641
3898·2	2		,,	,,	25646
3897·07	4		,,	,,	25653·0
3895·8	1n		1·07	,,	25662
3894·2	1		,,	,,	25672
3893·7	1		,,	,,	25676
3893·0	2		,,	,,	25680
3892·1	1		,,	,,	25686
3891·0	1		,,	,,	25693
3889·5	1n		,,	,,	25703
3888·7	1n		,,	,,	25709
3888·2	1		,,	,,	25712
3886·9	1		,,	,,	25720
3886·5	1		,,	,,	25723
3884·2	1		,,	,,	25738
3884·0	1		,,	,,	25740
3883·5	1n		,,	,,	25743
3882·7	1n		,,	,,	25748
3881·50	4		,,	,,	25755·9
3880·3	1		,,	,,	25764
3879·7	1		,,	,,	25768
3879·4	1		,,	,,	25770
3879·2	1		,,	,,	25772

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3878·7	1		1·07	7·3	25775
3878·3	1		,,	,,	25777
3877·9	1		,,	,,	25780
3877·5	2		,,	,,	25783
3876·2	1n		,,	,,	25791
3876·0	2		,,	,,	25793
3874·7	2		,,	,,	25801
3873·1	2		,,	,,	25812
3872·8	2n		,,	,,	25814
3871·8	1n		,,	,,	25821
3870·8	1n		,,	,,	25827
3869·6	1n		,,	,,	25835
3868·7	1		,,	,,	25841
3868·05	4		,,	,,	25845·5
3867·5	1		,,	,,	25849
3866·2	1		,,	,,	25858
3865·5	1		,,	,,	25863
3864·6	2		,,	,,	25869
3863·8	1		,,	,,	25874
3863·0	1		,,	,,	25880
3862·7	1		,,	,,	25882
3861·3	1		,,	,,	25891
3861·2	1		,,	,,	25893
3860·1	2		,,	,,	25899
3859·5	2		,,	,,	25903
3859·0	1		,,	,,	25906
3857·6	1		,,	,,	25916
3857·5	1		,,	,,	25917
3857·0	2		,,	,,	25920
3856·6	2		1·06	,,	25923
3856·2	1		,,	,,	25925
3855·7	1		,,	,,	25929
3855·5	1		,,	,,	25930
3854·8	1		,,	,,	25935
3854·0	1		,,	,,	25940
3853·0	1		,,	,,	25947
3851·70	4		,,	,,	25955·3
3851·3	1		,,	,,	25958
3850·2	1		,,	,,	25966
3847·7	2		,,	,,	25983
3846·32	4		,,	,,	25991·6
3846·0	1		,,	,,	25994
3844·5	1		,,	,,	26004
3843·8	1		,,	,,	26009
3843·5	1		,,	,,	26011
3842·6	2		,,	,,	26017
3841·2	1n		,,	,,	26027
3840·5	1		,,	,,	26031
3839·4	1		,,	,,	26039
3838·6	2		,,	,,	26044
3838·1	1		,,	,,	26048
3837·9	1		,,	,,	26049
3837·4	2		,,	,,	26052
3836·7	1		,,	,,	26057
3836·0	1n		,,	,,	26062

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3835·13	4		1·06	7·3	26067·4
3834·4	1		,,	,,	26073
3834·3	1		,,	,,	26073
3833·1	1		,,	,,	26082
3832·8	1		,,	,,	26084
3832·5	1		,,	,,	26086
3830·9	1n		,,	,,	26097
3830·7	1		,,	,,	26098
3830·4	1		,,	,,	26100
3830·0	1		,,	,,	26103
3829·3	1		,,	,,	26107
3828·1	2		,,	,,	26116
3827·4	1b		,,	,,	26120
3826·3	1		,,	,,	26128
3825·6	1		,,	,,	26133
3825·4	1		,,	,,	26134
3824·6	2		,,	,,	26140
3823·2	2		,,	,,	26149
3823·0	1		,,	,,	26150
3822·3	1		,,	,,	26155
3821·8	1n		,,	,,	26159
3820·6	2		,,	,,	26167
3819·2	1		,,	,,	26176
3819·1	1		,,	,,	26177
3818·0	1n		,,	,,	26185
3817·60	4		,,	7·4	26187·1
3816·5	2		1·05	,,	26195
3816·0	2		,,	,,	26198
3815·3	1n		,,	,,	26203
3814·6	1		,,	,,	26208
3813·2	1n		,,	,,	26218
3812·8	1n		,,	,,	26220
3810·9	2		,,	,,	26234
3810·5	2		,,	,,	26236
3810·0	1		,,	,,	26240
3809·3	2		,,	,,	26245
3807·8	1		,,	,,	26255
3807·5	1		,,	,,	26257
3806·8	1n		,,	,,	26262
3805·8	1		,,	,,	26269
3805·5	1		,,	,,	26271
3804·6	1		,,	,,	26277
3804·2	1		,,	,,	26280
3803·4	1		,,	,,	26285
3803·1	1		,,	,,	26287
3802·1	2		,,	,,	26294
3801·6	1		,,	,,	26298
3800·2	1		,,	,,	26307
3799·7	1		,,	,,	26311
3799·2	1		,,	,,	26314
3796·4	2n		,,	,,	26334
3795·0	1		,,	,,	26343
3794·4	2		,,	,,	26349
3793·5	1		,,	,,	26354
3792·8	2		,,	,,	26359

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3792·3	1		1·05	7·4	26362
3791·6	1		,,	,,	26367
3791·5	1		,,	,,	26368
3791·0	1n		,,	,,	26371
3790·1	2		,,	,,	26378
3788·0	1		,,	,,	26392
3786·5	1		,,	,,	26403
3786·2	1		,,	,,	26405
3783·9	1		,,	,,	26421
3783·6	1		,,	,,	26423
3782·9	1		,,	,,	26428
3782·0	1		,,	,,	26434
3781·5	1		,,	,,	26438
3780·91	4		,,	,,	26441·3
3778·3	1		,,	,,	26460
3777·5	2		,,	,,	26466
3775·5	2		1·04	,,	26480
3774·3	2		,,	,,	26488
3773·85	4		,,	,,	26490·7
3772·6	1		,,	7·5	26500
3772·2	1		,,	,,	26502
3770·0	1		,,	,,	26518
3769·4	1		,,	,,	26521
3768·62	4		,,	,,	26527·4
3768·0	1		,,	,,	26531
3767·5	1		,,	,,	26535
3767·3	1		,,	,,	26536
3767·0	1		,,	,,	26538
3765·5	1b		,,	,,	26549
3764·6	1		,,	,,	26555
3764·0	1		,,	,,	26559
3763·2	1		,,	,,	26565
3761·7	1		,,	,,	26576
3761·5	1		,,	,,	26577
3760·5	2		,,	,,	26584
3760·3	2		,,	,,	26586
3759·3	1		,,	,,	26593
3758·4	1		,,	,,	26599
3757·0	2n		,,	,,	26609
3755·0	1		,,	,,	26623
3754·9	1		,,	,,	26624
3753·7	2		,,	,,	26632
3753·3	1		,,	,,	26635
3751·5	1		,,	,,	26648
3750·8	1		,,	,,	26653
3748·4	1		,,	,,	26670
3747·9	1		,,	,,	26674
3747·6	1		,,	,,	26676
3747·0	1		,,	,,	26680
3745·70	4 Fe		,,	,,	26689·8
3744·4	1		,,	,,	26699
3744·2	1		,,	,,	26700
3743·5	1		,,	,,	26705
3742·7	1		,,	,,	26711
3741·9	4		,,	,,	26716

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3739·7	1		1·04	7·5	26732
3739·3	1		,,	,,	26735
3738·9	1		,,	,,	26738
3737·1	2b		1·03	,,	26751
3736·38	6		,,	,,	26756·4
3735·5	1		,,	,,	26762
3733·7	1		,,	,,	26775
3733·5	1		,,	,,	26777
3732·7	1n		,,	,,	26782
3732·1	1		,,	,,	26787
3731·9	1		,,	,,	26788
3730·6	1		,,	,,	26797
3729·9	1		,,	,,	26802
3729·4	1		,,	,,	26806
3728·5	1n		,,	,,	26812
3726·2	1		,,	7·6	26829
3725·3	1		,,	,,	26835
3724·6	1		,,	,,	26841
3722·7	1		,,	,,	26854
3721·3	2		,,	,,	26864
3720·7	1		,,	,,	26869
3720·0	2		,,	,,	26874
3719·6	2		,,	,,	26877
3718·7	1		,,	,,	26883
3718·4	1		,,	,,	26885
3718·0	1		,,	,,	26888
3717·3	1		,,	,,	26893
3716·20	4		,,	,,	26901·6
3715·1	1		,,	,,	26909
3715·0	1		,,	,,	26910
3714·8	1		,,	,,	26911
3714·3	1		,,	,,	26915
3713·8	1		,,	,,	26919
3713·2	1		,,	,,	26923
3712·3	2		,,	,,	26929
3711·6	1		,,	,,	26935
3711·0	1		,,	,,	26939
3709·4	1		,,	,,	26951
3708·68	4		,,	,,	26956·2
3708·09	4		,,	,,	26960·5
3706·2	1b		,,	,,	26974
3705·5	1		,,	,,	26979
3705·4	1		,,	,,	26980
3704·8	1		,,	,,	26984
3704·4	1		,,	,,	26987
3703·4	1		,,	,,	26994
3703·0	1		,,	,,	26997
3702·9	1		,,	,,	26998
3702·4	1		,,	,,	27002
3701·9	1		,,	,,	27005
3700·7	1n		,,	,,	27014
3699·5	1		,,	,,	27023
3698·7	1		,,	,,	27029
3698·6	1		,,	,,	27029
3697·5	1		1·02	,,	27037

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3696·9	1		1·02	7·6	27042
3696·5	1		,,	,,	27045
3696·2	1		,,	,,	27047
3694·70	4		,,	,,	27058·2
3693·8	1		,,	,,	27064
3693·6	1n Mo		,,	,,	27066
3692·8	4		,,	,,	27072
3692·00	4		,,	,,	27079·0
3690·3	2		,,	,,	27090
3689·9	1		,,	,,	27093
3689·7	2		,,	,,	27094
3689·2	1		,,	,,	27098
3688·6	1		,,	,,	27103
3688·4	2 Mo		,,	,,	27104
3688·1	2		,,	,,	27106
3687·4	2n		,,	,,	27111
3686·7	1		,,	,,	27117
3686·4	1		,,	,,	27119
3685·6	1		,,	,,	27125
3685·5	1		,,	,,	27125
3685·2	1		,,	,,	27128
3684·7	1		,,	,,	27131
3683·9	2		,,	,,	27137
3683·3	2		,,	7·7	27142
3682·22	4		,,	,,	27149·8
3680·8	1n		,,	,,	27165
3679·9	1		,,	,,	27167
3679·3	1		,,	,,	27171
3677·6	1		,,	,,	27184
3676·3	1		,,	,,	27193
3675·5	1		,,	,,	27199
3674·9	1		,,	,,	27204
3672·9	1		,,	,,	27218
3671·9	1n		,,	,,	27226
3671·5	1n		,,	,,	27229
3670·6	1n		,,	,,	27235
3670·2	1n		,,	,,	27238
3669·3	1		,,	,,	27245
3668·7	1		,,	,,	27250
3667·6	1		,,	,,	27258
3667·5	1		,,	,,	27259
3667·1	1n		,,	,,	27262
3665·7	1n		,,	,,	27272
3664·7	1n		,,	,,	27279
3663·7	1		,,	,,	27287
3663·3	1		,,	,,	27290
3661·6	1		,,	,,	27302
3661·2	1		,,	,,	27305
3660·1	1		,,	,,	27314
3659·2	1		,,	,,	27320
3658·05	4		,,	,,	27329·3
3657·75	6		1·01	,,	27331·5
3657·5	6		,,	,,	27333
3656·7	1		,,	,,	27339
3656·6	1		,,	,,	27340

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3655·5	1		1·01	7·7	27348
3654·7	1		,,	,,	27354
3654·2	2		,,	,,	27358
3653·3	2		,,	,,	27365
3651·5	1		,,	,,	27378
3650·0	1		,,	,,	27389
3649·0	1		,,	,,	27397
3647·9	1		,,	,,	27405
3646·72	6		,,	,,	27414·2
3645·78	6		,,	,,	27421·3
3644·3	1		,,	,,	27432
3644·0	1		,,	,,	27434
3643·6	1		,,	,,	27437
3643·5	1		,,	,,	27438
3643·1	1		,,	,,	27441
3642·8	1		,,	,,	27443
4641·55	8		,,	,,	27453·1
3640·1	1		,,	,,	27464
3640·0	1		,,	,,	27465
3639·2	1		,,	7·8	27471
3638·0	1		,,	,,	27480
3637·4	1		,,	,,	27484
3636·8	1		,,	,,	27489
3635·4	1n		,,	,,	27499
3635·2	1n Mo		,,	,,	27501
3633·8	1		,,	,,	27511
3633·4	1		,,	,,	27514
3632·7	1		,,	,,	27520
3631·5	1		,,	,,	27529
3631·0	1		,,	,,	27533
3630·9	1		,,	,,	27533
3630·4	1		,,	,,	27537
3630·2	1		,,	,,	27539
3629·1	2		,,	,,	27547
3626·5	1		,,	,,	27567
3625·8	1		,,	,,	27572
3625·5	1		,,	,,	27574
3625·1	1		,,	,,	27577
3624·3	1		,,	,,	27584
3623·6	1		,,	,,	27589
3623·1	1		,,	,,	27593
3622·9	1		,,	,,	27594
3621·4	1		,,	,,	27606
3620·7	1		,,	,,	27611
3620·0	1		,,	,,	27616
3619·6	1		,,	,,	27619
3619·3	1		,,	,,	27622
3618·5	1		,,	,,	27628
3617·72	6		1·00	,,	27633·9
3616·9	1		,,	,,	27640
3616·5	1		,,	,,	27643
3616·2	1		,,	,,	27645
3615·6	1		,,	,,	27650
3615·0	1		,,	,,	27655
3614·6	1		,,	,,	27658

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3613·97	8		1·00	7·8	27662·6
3612·00	4		,,	,,	27677·7
3611·0	1n		,,	,,	27685
3610·0	2		,,	,,	27693
3608·9	1		,,	,,	27701
3607·6	1n		,,	,,	27711
3607·3	2		,,	,,	27714
3606·7	1		,,	,,	27718
3606·4	1		,,	,,	27720
3605·6	1		,,	,,	27727
3605·2	1		,,	,,	27730
3604·1	1		,,	,,	27738
3603·9	1		,,	,,	27740
3603·0	1n		,,	,,	27747
3601·7	1		,,	,,	27757
3601·2	1		,,	,,	27761
3600·6	1n		,,	,,	27765
3599·0	1		,,	,,	27777
3597·8	1		,,	,,	27787
3596·3	1		,,	,,	27798
3595·6	1		,,	,,	27804
3595·2	1		,,	7·9	27807
3595·0	1		,,	,,	27808
3594·6	1		,,	,,	27812
3594·1	1		,,	,,	27815
3593·6	1		,,	,,	27819
3592·55	8		,,	,,	27827·5
3590·9	1		,,	,,	27840
3590·5	1n		,,	,,	27843
3589·9	1		,,	,,	27848
3589·7	1n		,,	,,	27849
3588·7	1n		,,	,,	27851
3587·1	1		,,	,,	27870
3586·3	1n		,,	,,	27876
3585·8	1n		,,	,,	27880
3585·3	1n		,,	,,	27884
3585·0	1		,,	,,	27886
3584·8	1		,,	,,	27888
3583·5	2		,,	,,	27898
3582·8	1		,,	,,	27903
3582·7	1		,,	,,	27904
3582·0	2		,,	,,	27909
3581·2	2		,,	,,	27916
3579·8	1n		,,	,,	27927
3578·6	1n		,,	,,	27936
3577·6	1		0·99	,,	27944
3576·0	1		,,	,,	27956
3575·3	2		,,	,,	27962
3574·0	1		,,	,,	27972
3573·5	1		,,	,,	27976
3572·6	8		,,	,,	27982·4
3572·2	1		,,	,,	27986
3571·0	1		,,	,,	27995
3570·3	2		,,	,,	28001
3569·8	1		,,	,,	28005

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3569·7	1		0·99	7·9	28007
3569·3	1		,,	,,	28009
3569·1	1		,,	,,	28010
3568·2	2		,,	,,	28017
3567·6	1		,,	,,	28022
3565·8	1		,,	,,	28036
3565·7	1		,,	,,	28037
3565·5	1		,,	,,	28039
3564·5	1		,,	,,	28046
3564·2	1		,,	,,	28049
3563·6	1		,,	,,	28054
3562·6	2		,,	,,	28061
3561·5	2		,,	,,	28070
3559·8	1		,,	,,	28083
3559·0	1		,,	,,	28090
3558·5	1		,,	,,	28094
3558·4	1		,,	,,	28095
3557·3	1		,,	,,	28103
3557·2	1		,,	,,	28104
3556·1	1		,,	,,	28113
3555·35	4		,,	,,	28118·7
3554·6	1		,,	,,	28125
3554·1	1		,,	,,	28129
3554·0	1		,,	,,	28129
3553·0	1		,,	,,	28137
3552·3	1		,,	,,	28143
3551·6	1		,,	8·0	28148
3551·0	1		,,	,,	28153
3550·8	1		,,	,,	28155
3550·2	1		,,	,,	28159
3549·23	6		,,	,,	28167·1
3548·3	2		,,	,,	28175
3546·5	1		,,	,,	28189
3545·40	4		,,	,,	28197·6
3544·6	2		,,	,,	28204
3544·3	1		,,	,,	28206
3543·3	2		,,	,,	28214
3542·3	1		,,	,,	28222
3541·7	1		,,	,,	28227
3541·3	1n		,,	,,	28230
3540·8	1		,,	,,	28234
3540·4	1		,,	,,	28237
3540·0	1		,,	,,	28241
3539·5	1		,,	,,	28245
3538·6	1		,,	,,	28252
3538·2	1		,,	,,	28255
3537·5	2		0·98	,,	28261
3536·47	4		,,	,,	28268·8
3535·6	2		,,	,,	28276
3535·4	1		,,	,,	28277
3534·5	2		,,	,,	28285
3532·8	1		,,	,,	28298
3532·7	1		,,	,,	28299
3531·4	1		,,	,,	28309
3531·1	1		,,	,,	28312

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3530·9	1		0·98	8·0	28313
3530·7	1		"	"	28315
3529·72	4		"	"	28322·9
3528·9	1		"	"	28329
3528·8	1		"	"	28330
3528·1	1		"	"	28336
3527·8	1		"	"	28338
3526·9	2		"	"	28346
3525·7	2		"	"	28355
3524·6	1		"	"	28364
3524·3	1		"	"	28366
3523·6	1		"	"	28372
3523·2	1		"	"	28375
3522·2	1		"	"	28383
3522·1	1		"	"	28384
3521·0	1		"	"	28393
3520·2	1n		"	"	28399
3518·9	1		"	"	28410
3518·6	1		"	"	28412
3517·5	1		"	"	28421
3517·1	1		"	"	28425
3516·3	1		"	"	28431
3516·1	1		"	"	28433
3515·1	1		"	"	28441
3514·3	1		"	"	28447
3513·0	1		"	"	28458
3512·2	2		"	"	28464
3511·8	1		"	"	28467
3511·3	2		"	"	28471
3510·6	1		"	8·1	28477
3510·1	2		"	"	28481
3509·4	2		"	"	28487
3509·1	1		"	"	28489
3508·89	6		"	"	28490·9
3508·0	1		"	"	28498
3507·3	1		"	"	28504
3506·6	1		"	"	28510
3506·3	1n		"	"	28512
3504·9	1		"	"	28523
3504·8	1		"	"	28524
3503·88	4		"	"	28531·7
3503·1	1		"	"	28538
3502·2	1		"	"	28545
3501·4	1n		"	"	28552
3500·3	1		"	"	98561
3499·7	1		"	"	28566
3498·9	1		0·97	"	28572
3498·2	1		"	"	28578
3498·0	1		"	"	28580
3496·9	1		"	"	28589
3496·0	1		"	"	28595·9
3495·40	4		"	"	28601
3493·2	1b		"	"	28619
3492·1	2		"	"	28628
3491·2	2		"	"	28635

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3490·3	2		0·97	8·1	28643
3489·9	1		"	"	28646
3489·5	1n		"	"	28650
3488·7	1		"	"	28656
3488·6	1		"	"	28657
3487·1	1		"	"	28669
3486·32	4		"	"	28675·4
3485·5	1		"	"	28682
3485·3	1		"	"	28684
3483·5	1		"	"	28699
3482·8	1		"	"	28705
3481·5	1		"	"	28715
3480·6	1		"	"	28723
3480·3	1		"	"	28725
3479·0	1n		"	"	28736
3478·0	2		"	"	28744
3477·2	2		"	"	28751
3476·6	2		"	"	28756
3475·55	4		"	"	28764·3
3475·45	4		"	"	28765·2
3474·2	1n		"	"	28776
3473·0	1		"	"	28786
3472·4	1		"	"	28791
3471·9	1		"	"	28795
3470·5	1n		"	8·2	28806
3470·2	1n		"	"	28809
3469·3	1n		"	"	28816
3468·3	2		"	"	28825
3468·0	1		"	"	28827
3467·6	1		"	"	28830
3467·0	1		"	"	28835
3466·5	1		"	"	28840
3466·0	1		"	"	28844
3465·2	1		"	"	28850
3464·6	2		"	"	28855
3463·70	6		"	"	28862·7
3462·7	1n		"	"	28871
3462·2	1n		"	"	28875
3461·7	1		"	"	28880
3460·3	1		"	"	28891
3459·8	1		"	"	28895
3459·6	1		"	"	28897
3458·8	1		0·96	"	28904
3458·4	1		"	"	28907
3457·8	1		"	"	28912
3456·5	1		"	"	28923
3455·1	2		"	"	28935
3454·0	1		"	"	28944
3452·9	1n		"	"	28953
3452·6	2		"	"	28956
3452·0	1		"	"	28961
3451·9	1		"	"	28962
3451·3	1		"	"	28967
3450·8	1		"	"	28971
3450·3	1		"	"	28975

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3450·00	4		0·96	8·2	28977·3
3449·5	1		"	"	28982
3449·0	1		"	"	28986
3448·4	2		"	"	28991
3448·2	1		"	"	28993
3448·0	1		"	"	28994
3447·0	1		"	"	29003
3446·6	1		"	"	29006
3445·8	1		"	"	29013
3445·6	1		"	"	29015
3445·3	1		"	"	29017
3444·7	1		"	"	29022
3444·2	1		"	"	29026
3443·2	2		"	"	29035
3442·1	1		"	"	29044
3440·80	6 Fe		"	"	29054·8
3438·8	1		"	"	29072
3438·2	1		"	"	29077
3435·7	2		"	"	29098
3434·8	1		"	"	29106
3433·9	1		"	"	29113
3432·6	1n		"	8·3	29124
3432·3	1n		"	"	29127
3431·7	1n		"	"	29132
3430·8	2n		"	"	29140
3430·4	1		"	"	29143
3429·7	2		"	"	22149
3429·4	1		"	"	29152
3427·8	2		"	"	29165
3426·3	1		"	"	29178
3426·0	1		"	"	29181
3425·6	1		"	"	29184
3424·9	1n		"	"	29190
3424·6	2		"	"	29192
3423·3	1		"	"	29204
3422·8	1		"	"	29208
3421·4	1		"	"	29220
3420·2	2		"	"	29230
3419·3	1		"	"	29238
3418·6	1		"	"	29244
3418·4	1		"	"	29245
3417·7	1		0·95	"	29251
3417·6	1		"	"	29252
3416·78	4		"	"	29259·0
3415·4	2n		"	"	29271
3414·7	1		"	"	29277
3413·6	2		"	"	29287
3412·8	2		"	"	29293
3412·0	1n		"	"	29300
3411·0	1		"	"	29309
3409·3	1n		"	"	29324
3407·6	2		"	"	29338
3406·9	2		"	"	29344
3406·7	2		"	"	29346
3406·2	1		"	"	29350

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3406·1	1		0·95	8·3	29351
3405·3	1		,,	,,	29358
3404·8	1		,,	,,	29362
3404·3	1		,,	,,	29367
3404·2	1		,,	,,	29367
3403·8	1		,,	,,	29371
3402·8	1		,,	,,	29380
3402·2	1		,,	,,	29385
3402·03	6		,,	,,	29385·9
3401·5	1		,,	,,	29391
3401·0	1		,,	,,	29395
3400·7	1		,,	,,	29398
3400·2	1		,,	,,	29402
3399·07	6		,,	,,	29411·5
3398·3	2		,,	,,	29418
3397·7	1		,,	,,	29424
3397·4	1		,,	,,	29426
3396·5	1		,,	8·4	29434
3396·0	1		,,	,,	29438
3395·0	1		,,	,,	29447
3394·6	2		,,	,,	29451
3393·7	1n		,,	,,	29458
3393·1	1		,,	,,	29464
3392·5	1		,,	,,	29469
3391·7	1		,,	,,	29476
3391·3	1		,,	,,	29479
3390·5	2n		,,	,,	29486
3389·7	1		,,	,,	29493
3389·0	2		,,	,,	29499
3387·8	2		,,	,,	29510
3387·0	1		,,	,,	29517
3386·7	1		,,	,,	29519
3386·2	1		,,	,,	29524
3386·0	1		,,	,,	29525
3385·1	1		,,	,,	29534
3384·5	1		,,	,,	29538
3384·4	1		,,	,,	29539
3384·0	1		,,	,,	29543
3383·3	2		,,	,,	29549
3382·4	1		,,	,,	29557
3382·0	1		,,	,,	29560
3381·2	2		,,	,,	29567
3379·8	1		,,	,,	29580
3379·3	2		,,	,,	29584
3378·7	1		,,	,,	29589
3378·4	1		,,	,,	29592
3378·3	1		,,	,,	29593
3377·5	1		0·94	,,	29600
3377·0	1		,,	,,	29604
3376·23	8		,,	,,	29610·4
3375·3	1		,,	,,	29619
3374·3	1		,,	,,	29628
3373·4	1		,,	,,	29636
3373·0	1		,,	,,	29639
3372·4	2		,,	,,	23644

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3371·7	1		0·94	8·4	29651
3371·3	1		,,	,,	29654
3370·7	1		,,	,,	29659
3370·4	1		,,	,,	29662
3370·0	1		,,	,,	29666
3369·9	1		,,	,,	29666
3369·2	1		,,	,,	29673
3368·3	1n		,,	,,	29681
3367·8	1		,,	,,	29685
3367·5	1		,,	,,	29688
3366·8	2		,,	,,	29694
3366·5	1		,,	,,	29696
3366·0	1		,,	,,	29701
3365·3	1		,,	,,	29707
3364·9	1		,,	,,	29711
3364·0	2		,,	,,	29719
3363·5	2		,,	,,	29723
3362·5	1		,,	,,	29732
3362·1	1		,,	,,	29735
3361·20	4		,,	,,	29742·9
3360·5	2		,,	8·5	29748
3359·3	1		,,	,,	29759
3358·72	6		,,	,,	29764·8
3357·8	1		,,	,,	29772
3357·2	1		,,	,,	29778
3356·5	1b		,,	,,	29784
3355·9	1		,,	,,	29789
3355·5	1		,,	,,	29793
3355·1	1		,,	,,	29796
3354·7	2		,,	,,	29800
3354·2	1		,,	,,	29804
3354·0	1		,,	,,	29806
3353·8	1		,,	,,	29808
3353·1	2		,,	,,	29814
3352·5	2		,,	,,	29819
3352·0	1		,,	,,	29824
3351·6	1n		,,	,,	29828
3350·2	1		,,	,,	29840
3349·6	1		,,	,,	29845
3349·4	2		,,	,,	29847
3349·0	2		,,	,,	29851
3348·4	2		,,	,,	29856
3347·8	1		,,	,,	29861
3347·2	1		,,	,,	29867
3346·2	1		,,	,,	29876
3345·8	2		,,	,,	29879
3345·6	1		,,	,,	29881
3344·5	1		,,	,,	29891
3343·60	4		,,	,,	29899·4
3343·28	4		,,	,,	29902·2
3342·63	6		,,	,,	29908·1
3341·3	1		,,	,,	29919
3340·3	1		,,	,,	29928
3339·7	1		,,	,,	29934
3339·1	2		,,	,,	29939

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3338·7	2		0·93	8·5	29943
3338·3	1		,,	,,	29946
3338·0	1n		,,	,,	29949
3336·7	2		,,	,,	29961
3336·1	1		,,	,,	29966
3335·6	1		,,	,,	29971
3334·8	1		,,	,,	29978
3334·0	1		,,	,,	29985
3331·7	2		,,	,,	30006
3330·8	1n		,,	,,	30014
3328·2	1		,,	,,	30037
3327·8	1		,,	,,	30041
3327·2	1		,,	,,	30046
3326·3	2		,,	,,	30054
3326·2	1		,,	,,	30055
3325·7	1		,,	,,	30060
3325·0	1		,,	8·6	30066
3324·2	1		,,	,,	30073
3323·5	1		,,	,,	30080
3322·6	1		,,	,,	30088
3321·7	1		,,	,,	30096
3321·2	1		,,	,,	30101
3321·1	1		,,	,,	30102
3320·5	1		,,	,,	30107
3320·4	1		,,	,,	30108
3319·6	1		,,	,,	30115
3318·7	1		,,	,,	30123
3318·5	1		,,	,,	30125
3318·0	1		,,	,,	30130
3317·0	1		,,	,,	30139
3316·1	1		,,	,,	30147
3315·2	1		,,	,,	30155
3314·4	1		,,	,,	30162
3313·6	1		,,	,,	30170
3312·4	1		,,	,,	30181
3311·6	2		,,	,,	30188
3310·3	2		,,	,,	30200
3309·6	1		,,	,,	30206
3309·2	1		,,	,,	30210
3308·3	2		,,	,,	30218
3306·2	4n Fe		,,	,,	30237
3305·5	1		,,	,,	30244
3304·6	2		,,	,,	30252
3304·5	1		,,	,,	30253
3303·8	1		,,	,,	30259
3303·3	1		,,	,,	30264
3303·0	1		,,	,,	30267
3302·0	1		,,	,,	30276
3301·3	1		,,	,,	30282
3301·0	2		,,	,,	30285
3300·5	1		,,	,,	30289
3299·7	1		0·92	,,	30297
3298·8	1		,,	,,	30305
3298·3	2		,,	,,	30310
3297·5	2		,,	,,	30317

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3296·3	1		0·92	8·6	30328
3295·2	1		,,	,,	30338
3294·3	1n		,,	,,	30346
3293·8	2		,,	,,	30351
3293·0	1		,,	,,	30358
3291·7	1		,,	,,	30370
3291·5	1		,,	,,	30372
3291·1	1		,,	,,	30376
3291·0	1		,,	,,	30377
3290·6	1		,,	,,	30381
3290·3	1		,,	,,	30383
3290·1	1n		,,	,,	30385
3288·8	1n		,,	8·7	30397
3288·0	1n		,,	,,	30405
3286·70	4		,,	,,	30417·0
3285·8	2n		,,	,,	30425
3283·7	2n		,,	,,	30444
3282·7	1n		,,	,,	30454
3282·0	2		,,	,,	30460
3280·2	1n		,,	,,	30477
3279·5	1n		,,	,,	30483
3277·8	1		,,	,,	30499
3277·6	1n		,,	,,	30501
3277·0	1		,,	,,	30507
3276·5	1n		,,	,,	30511
3275·7	1n		,,	,,	30519
3274·9	1n		,,	,,	30526
3273·2	1n		,,	,,	30542
3272·0	1		,,	,,	30553
3271·7	1n		,,	,,	30555
3270·3	1		,,	,,	30569
3270·2	1		,,	,,	30570
3269·7	1		,,	,,	30575
3269·0	1		,,	,,	30581
3268·6	1		,,	,,	30585
3268·3	2		,,	,,	30588
3267·6	2		,,	,,	30595
3266·7	2		,,	,,	30603
3266·0	2		,,	,,	30609
3265·2	2		,,	,,	30617
3264·2	1		,,	,,	30626
3263·2	1		,,	,,	30636
3262·37	4		,,	,,	30643·9
3261·2	1		,,	,,	30655
3260·8	1		,,	,,	30658
3260·3	1		,,	,,	30663
3259·4	1		0·91	,,	30671
3257·8	1		,,	,,	30687
3256·1	1		,,	,,	30703
3255·7	1		,,	,,	30706
3255·0	2		,,	,,	30713
3254·3	2		,,	,,	30720
3252·5	1n		,,	8·8	30737
3251·2	2		,,	,,	30749
3250·2	1		,,	,,	30758

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
3248·7	1		0·91	8·8	30773
3247·9	1		,,	,,	30780
3247·6	1		,,	,,	30783
3246·4	1		,,	,,	30794
3245·4	1		,,	,,	30804
3243·50	4		,,	,,	30822·1
3243·2	2		,,	,,	30825
3242·1	2		,,	,,	30835
3241·4	1		,,	,,	30842
3241·2	1		,,	,,	30844
3240·0	1n		,,	,,	30855
3238·9	1		,,	,,	30866
3238·5	1		,,	,,	30869
3238·3	1		,,	,,	30871
3237·2	1		,,	,,	30882
3236·0	1		,,	,,	30893
3235·9	1		,,	,,	30894
3235·1	1		,,	,,	30902
3234·6	1		,,	,,	30907
3233·8	1		,,	,,	30914
3233·3	2		,,	,,	30919
3232·6	1		,,	,,	30926
3232·2	1		,,	,,	30930
3231·6	1		,,	,,	30935
3230·9	1		,,	,,	30942
3229·7	1		,,	,,	30954
3229·5	1		,,	,,	30956
3229·0	1		,,	,,	30960
3227·9	1		,,	,,	30971
3227·7	1		,,	,,	30973
3226·7	2		,,	,,	30982
3224·9	1		,,	,,	31000
3224·0	1		,,	,,	31008
3223·3	1n		,,	,,	31015
3222·7	1		,,	,,	31021
3222·1	1		,,	,,	31027
3221·3	2		,,	,,	31034
3221·1	1n		,,	,,	31036
3220·2	1		0·90	,,	31045
3220·0	1		,,	,,	31047
3218·9	1		,,	,,	31058
3218·7	1		,,	,,	31059
3217·6	1		,,	,,	31070
3216·3	2		,,	8·9	31083
3215·68	4		,,	,,	31088·7
3215·3	2		,,	,,	31092
3214·4	1		,,	,,	31101
3214·1	1		,,	,,	31104
3213·4	1		,,	,,	31111
3213·2	1		,,	,,	31113
3212·1	1		,,	,,	31123
3211·9	1		,,	,,	31125
3211·2	1		,,	,,	31132
3210·9	1		,,	,,	31135
3210·7	1		,,	,,	31137

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Angström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3210·0	2		0·90	8·9	31144
3208·6	1		,,	,,	31157
3208·3	1		,,	,,	31160
3208·2	1		,,	,,	31161
3207·8	1		,,	,,	31165
3207·6	1		,,	,,	31167
3207·3	2		,,	,,	31170
3206·7	1		,,	,,	31176
3206·4	2		,,	,,	31179
3205·7	1		,,	,,	31185
3205·6	1		,,	,,	31186
3205·3	1		,,	,,	31189
3204·5	1		,,	,,	31197
3203·7	1		,,	,,	31205
3203·43	4		,,	,,	31207·6
3202·2	1		,,	,,	31220
3202·0	1		,,	,,	31221
3201·7	2		,,	,,	31224
3200·5	1n		,,	,,	31236
3200·1	1		,,	,,	31240
3199·4	1		,,	,,	31247
3199·0	2		,,	,,	31251
3198·4	2		,,	,,	31257
3197·5	2		,,	,,	31265
3196·5	1		,,	,,	31275
3196·0	1		,,	,,	31280
3195·8	1		,,	,,	31282
3194·7	2b		,,	,,	31293
3193·8	2		,,	,,	31302
3193·2	1		,,	,,	31308
3193·0	1		,,	,,	31310
3192·3	1		,,	,,	31316
3192·2	1		,,	,,	31317
3191·6	2		,,	,,	31323
3191·0	2		,,	,,	31329
3189·3	2		,,	,,	31346
3188·5	1		,,	,,	31354
3188·0	1		,,	,,	31359
3187·8	1		,,	,,	31361
3187·1	2		,,	,,	31367
3186·4	1		,,	,,	31374
3185·0	1		,,	,,	31388
3184·4	1		,,	,,	31394
3184·0	1		,,	,,	31398
3183·5	1		,,	,,	31403
3182·8	1		,,	,,	31410
3182·2	1		,,	,,	31416
3181·8	1		0·89	,,	31420
3180·8	1		,,	9·0	31430
3180·2	1		,,	,,	31436
3179·60	4n		,,	,,	31441·5
3178·7	1n		,,	,,	31450
3178·1	2		,,	,,	31456
3177·2	2		,,	,,	31465
3176·7	1		,,	,,	31470

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3176·10	4		0·89	9·0	31476·2
3175·1	1		"	"	31486
3174·7	1		"	"	31490
3173·6	1		"	"	31501
3172·8	1		"	"	31509
3171·6	1		"	"	31521
3171·4	1		"	"	31523
3170·2	1		"	"	31535
3170·0	1		"	"	31537
3168·5	1n		"	"	31552
3167·9	1		"	"	31558
3167·7	1		"	"	31560
3167·0	1		"	"	31567
3166·5	1n		"	"	31572
3165·7	1		"	"	31580
3165·4	1		"	"	31583
3164·8	1		"	"	31589
3164·5	1		"	"	31592
3164·4	1		"	"	31593
3163·5	2		"	"	31602
3162·2	1		"	"	31615
3162·0	1		"	"	31617
3161·3	1		"	"	31624
3160·7	1		"	"	31630
3160·20	4		"	"	31634·6
3159·0	4b		"	"	31647
3157·0	1n		"	"	31667
3155·7	1		"	"	31680
3155·5	1		"	"	31682
3155·2	1		"	"	31685
3154·2	1		"	"	31695
3152·8	1		"	"	31709
3152·4	2		"	"	31713
3151·6	1		"	"	31721
3151·3	2		"	"	31724
3149·9	2		"	"	31738
3149·8	1		"	"	31739
3148·1	1		"	"	31756
3147·9	1		"	"	31758
3146·8	1		"	9·1	31769
3146·3	2		"	"	31774
3145·7	2		"	"	31780
3145·5	1		"	"	31782
3144·5	2		"	"	31793
3143·3	2		"	"	31805
3143·0	1		"	"	31808
3142·9	1		"	"	31809
3142·0	4		"	"	31818
3141·3	2		0·88	"	31825
3140·3	1		"	"	31835
3140·2	1		"	"	31836
3139·4	1		"	"	31844
3138·7	1		"	"	31851
3137·9	1		"	"	31859
3137·6	1		"	"	31862

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
3137·2	1		0·88	9·1	31867
3135·9	1		"	"	31880
3135·8	1		"	"	31881
3133·8	2		"	"	31901
3132·6	1		"	"	31913
3131·2	1		"	"	31928
3130·4	1		"	"	31936
3129·7	2		"	"	31943
3129·0	2		"	"	31950
3127·7	2		"	"	31963
3127·3	1		"	"	31967
3126·3	2		"	"	31978
3125·7	1		"	"	31984
3125·3	1		"	"	31988
3124·5	1n		"	"	31996
3123·5	2		"	"	32006
3121·9	1n Mo		"	"	32023
3121·0	1		"	"	32032
3120·7	1		"	"	32035
3120·1	2		"	"	32041
3119·6	1		"	"	32046
3119·4	1		"	"	32048
3118·3	1		"	"	32060
3117·5	2		"	"	32068
3116·0	1n		"	"	32083
3115·4	1		"	"	32090
3115·3	1		"	"	32091
3113·6	1		"	"	32108
3113·3	1		"	9·2	32111
3112·7	2		"	"	32117
3112·4	1		"	"	32121
3112·3	1		"	"	32122
3111·8	1		"	"	32127
3111·1	2		"	"	32134
3110·6	2		"	"	32139
3108·6	2		"	"	32160
3108·3	1		"	"	32163
3107·9	2		"	"	32167
3107·5	1		"	"	32171
3107·2	2		"	"	32174
3106·5	2		"	"	32185
3106·1	1		"	"	32186
3105·9	1		"	"	32188
3104·9	1		"	"	32198
3104·3	1		"	"	32204
3103·7	1		"	"	32211
3103·4	1		"	"	32214
3103·0	1n		"	"	32218
3102·2	2		"	"	32226
3101·2	1		0·87	"	32237
3100·7	2		"	"	32242
3100·2	1n		"	"	32247
3099·0	1		"	"	32259
3098·7	1		"	"	32263
3098·4	1		"	"	32266

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3096·5	1		0.87	9·2	32286
3096·0	2		,,	,,	32291
3095·3	1		,,	,,	32298
3095·0	1		,,	,,	32301
3094·7	1		,,	,,	32304
3094·0	1		,,	,,	32312
3093·6	2		,,	,,	32316
3093·3	1		,,	,,	32319
3092·3	1		,,	,,	32329
3091·9	1		,,	,,	32334
3091·7	1		,,	,,	32336
3091·2	1		,,	,,	32341
3090·7	1		,,	,,	32346
3090·5	1		,,	,,	32348
3089·2	1		,,	,,	32362
3089·1	1		,,	,,	32363
3088·3	1		,,	,,	32371
3088·1	1		,,	,,	32373
3087·5	2		,,	,,	32380
3086·4	2		,,	,,	32391
3085·4	1		,,	,,	32402
3085·0	2		,,	,,	32406
3084·4	1		,,	,,	32412
3083·6	2		,,	9·3	32421
3083·2	1		,,	,,	32425
3082·2	2		,,	,,	32435
3081·9	2		,,	,,	32439
3081·1	2		,,	,,	32447
3080·7	1		,,	,,	32451
3080·0	1		,,	,,	32459
3079·3	1		,,	,,	32466
3079·0	1		,,	,,	32469
3078·3	1		,,	,,	32476
3077·63	6		,,	,,	32483·2
3076·9	1		,,	,,	32491
3076·0	2		,,	,,	32501
3075·3	1n		,,	,,	32508
3074·0	2		,,	,,	32522
3073·3	2		,,	,,	32529
3072·7	2		,,	,,	32536
3071·8	2		,,	,,	32545
3071·3	2		,,	,,	32551
3069·3	2		,,	,,	32572
3068·6	1		,,	,,	32579
3068·2	1		,,	,,	32583
3067·9	2		,,	,,	32587
3067·6	2		,,	,,	32590
3067·0	2		,,	,,	32596
3065·1	1		,,	,,	32616
3065·0	1		,,	,,	32617
3064·1	2		,,	,,	32627
3063·3	1		,,	,,	32636
3063·0	1		,,	,,	32639
3062·8	1		0·86	,,	32641
3061·7	2		,,	,,	32653

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
3061·0	1		0·86	9·3	32660
3059·8	1		”	”	32673
3059·7	1		”	”	32674
3059·1	1		”	”	32680
3058·5	2		”	”	32687
3057·5	1		”	”	32697
3056·2	1n		”	”	32711
3055·7	1		”	”	32717
3055·5	1		”	”	32719
3055·1	1		”	”	32723
3055·0	1		”	”	32724
3054·1	1		”	9·4	32734
3053·5	2		”	”	32740
3051·8	1		”	”	32759
3051·42	4		”	”	32762·2
3050·6	1		”	”	32771
3050·0	2		”	”	32778
3049·8	2		”	”	32780
3049·0	1		”	”	32789
3048.6	2		”	”	32793
3047·6	2		”	”	32804
3047·1	2		”	”	32809
3046·5	2		”	”	32816
3045·6	1		”	”	32825
3045·2	1		”	”	32830
3044·4	1		”	”	32838
3043·7	2		”	”	32846
3042·2	1n		”	”	32862
3041·8	2		”	”	32866
3041·0	1n		”	”	32875
3040·3	1		”	”	32882
3039·6	2		”	”	32890
3039·3	2		”	”	32893
3038·7	1		”	”	32900
3038·0	1		”	”	32907
3037·7	1		”	”	32911
3037·4	1		”	”	32914
3036·7	2		”	”	32921
3035·4	1		”	”	32936
3035·2	1		”	”	32938
3034·2	1		”	”	32949
3033·9	1		”	”	32952
3033·7	2		”	”	32954
3032·5	2		”	”	32967
3032·0	2n		”	”	32973
3031·0	2		”	”	32983
3030·3	1		”	”	32991
3029·9	1		”	”	32995
3029·5	1		”	”	33000
3028·9	1		”	”	33006
3028·7	1		”	”	33008
3027·8	1		”	”	33018
3027·3	1		”	”	33024
3026·7	2		”	”	33030
3025·9	1		”	”	33039

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
3025·2	1		0·86	9·5	33047
3024·9	1		,,	,,	33050
3024·58	4		,,	,,	33052·9
3023·6	1		,,	,,	33063
3022·9	1		0·85	,,	33071
3022·7	1		,,	,,	33073
3022·6	1		,,	,,	33074
3021·7	1n		,,	,,	33084
3021·0	1		,,	,,	33092
3020·7	2		,,	,,	33095
3020·3	1n		,,	,,	33099
3019·6	1		,,	,,	33107
3019·4	1		,,	,,	33109
3018·6	2		,,	,,	33118
3017·9	1		,,	,,	33126
3017·4	2		,,	,,	33131
3017·1	1		,,	,,	33134
3015·6	1		,,	,,	33151
3014·9	1		,,	,,	33159
3014·6	1		,,	,,	33162
3013·7	1		,,	,,	33172
3013·2	1		,,	,,	33177
3012·1	1		,,	,,	33189
3011·7	1		,,	,,	33194
3011·2	1		,,	,,	33199
3011·0	1		,,	,,	33202
3010·7	2		,,	,,	33205
3009·6	1		,,	,,	33217
3008·8	2		,,	,,	33226
3008·0	1		,,	,,	33235
3006·5	1		,,	,,	33251
3006·3	1		,,	,,	33253
3005·3	1		,,	,,	33265
3004·8	1		,,	,,	33270
3004·2	1		,,	,,	33277
3004·0	1		,,	,,	33279
3003·7	1		,,	,,	33282
3003·0	1		,,	,,	33290
3002·8	1		,,	,,	33292
3002·2	2		,,	,,	33299
3001·9	1		,,	,,	33302
3000·9	1		,,	,,	33313
3000·6	2		,,	,,	33317
3000·3	1		,,	,,	33320
2999·6	1		,,	,,	33328
2998·7	2		,,	,,	33338
2998·0	1		,,	,,	33346
2997·7	1		,,	,,	33349
2997·6	1		,,	9·6	33350
2996·9	1		,,	,,	33358
2996·5	1		,,	,,	33362
2996·0	1		,,	,,	33368
2995·7	1		,,	,,	33371
2995·4	1		,,	,,	33375
2995·3	2		,,	,,	33376

TUNGSTEN (SPARK SPECTRUM)– *continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2994·8	2		0·85	9·6	33381
2994·7	1		,,	,,	33382
2993·6	2		,,	,,	33395
2992·9	1		,,	,,	33402
2992·0	2		,,	,,	33412
2991·5	1		,,	,,	33418
2990·7	1		,,	,,	33427
2989·5	1		,,	,,	33440
2988·8	1		,,	,,	33448
2988·6	1		,,	,,	33450
2987·3	2		,,	,,	33465
2986·4	1		,,	,,	33475
2986·1	1		,,	,,	33478
2985·9	1		,,	,,	33481
2984·9	1		,,	,,	33492
2984·5	1		,,	,,	33496
2984·2	1		,,	,,	33500
2983·6	1		,,	,,	33507
2983·2	1		,,	,,	33511
2982·6	1		0·84	,,	33518
2982·3	2		,,	,,	33521
2981·6	1		,,	,,	33529
2980·7	1n		,,	,,	33539
2979·9	2		,,	,,	33548
2979·2	1		,,	,,	33556
2978·3	1		,,	,,	33566
2978·0	1		,,	,,	33570
2977·6	2		,,	,,	33574
2977·2	2		,,	,,	33579
2976·9	1		,,	,,	33582
2976·5	2		,,	,,	33587
2975·7	1n		,,	,,	33596
2975·1	1		,,	,,	33602
2974·4	2		,,	,,	33610
2973·3	1		,,	,,	33623
2973·1	1		,,	,,	33625
2972·9	1		,,	,,	33627
2972·5	1		,,	,,	33632
2971·7	1		,,	,,	33641
2971·4	1		,,	,,	33644
2971·0	1		,,	9·7	33649
2970·4	1		,,	,,	33655
2970·0	1		,,	,,	33660
2969·8	1		,,	,,	33662
2969·1	1		,,	,,	33670
2969·0	1		,,	,,	33671
2968·0	2		,,	,,	33683
2967·1	1		,,	,,	33693
2967·0	1		,,	,,	33694
2966·7	1		,,	,,	33697
2966·2	1		,,	,,	33703
2965·6	1		,,	,,	33710
2965·0	1		,,	,,	33717
2964·5	2		,,	,,	33722
2962·6	1		,,	,,	33744

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2961·8	1		0·84	9·7	33753
2961·0	2		,,	,,	33762
2960·3	1		,,	,,	33770
2960·1	1		,,	,,	33773
2960·0	1		,,	,,	33774
2959·0	1n		,,	,,	33785
2958·0	1		,,	,,	33797
2957·4	1		,,	,,	33803
2957·3	1		,,	,,	33805
2956·8	1		,,	,,	33810
2956·5	1		,,	,,	33814
2955·3	1		,,	,,	33828
2955·0	2		,,	,,	33831
2954·0	1		,,	,,	33842
2953·9	1		,,	,,	33844
2953·0	1		,,	,,	33854
2952·3	4		,,	,,	33862
2951·0	1		,,	,,	33877
2950·5	2		,,	,,	33883
2949·2	1		,,	,,	33898
2948·5	1		,,	,,	33906
2948·3	1		,,	,,	33908
2947·8	1n		,,	,,	33914
2947·5	1		,,	,,	33917
2947·0	2		,,	,,	33923
2946·0	1n		,,	,,	33934
2945·3	1		,,	9·8	33942
2944·6	2		,,	,,	33950
2943·5	1		,,	,,	33963
2943·2	1		,,	,,	33967
2942·7	1		0·83	,,	33972
2942·3	1		,,	,,	33977
2941·6	1		,,	,,	33985
2941·4	1		,,	,,	33987
2941·1	1		,,	,,	33991
2940·8	1		,,	,,	33994
2940·3	2		,,	,,	34000
2939·0	2n		,,	,,	34015
2937·7	1		,,	,,	34030
2937·2	1		,,	,,	34036
2936·7	2		,,	,,	34042
2935·7	1		,,	,,	34053
2935·3	1		,,	,,	34058
2935·0	2		,,	,,	34062
2933·0	1		,,	,,	34085
2932·7	1		,,	,,	34088
2932·0	1		,,	,,	34096
2931·6	1		,,	,,	34101
2931·0	1		,,	,,	34108
2930·0	2		,,	,,	34120
2929·1	1		,,	,,	34130
2928·7	1		,,	,,	34135
2928·2	1		,,	,,	34141
2928·0	1		,,	,,	34143
2927·9	1		,,	,,	34144

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2927·1	1		0·83	9·8	34154
2927·0	1		"	"	34155
2925·9	2		"	"	34168
2925·1	2		"	"	34177
2924·1	1		"	"	34189
2923·6	2		"	"	34194
2923·2	1		"	"	34199
2922·0	1		"	"	34213
2921·2	1		"	9·9	34223
2921·1	1		"	"	34224
2919·6	1		"	"	34241
2919·1	1		"	"	34247
2918·7	2		"	"	34252
2918·3	1		"	"	34257
2917·7	1n		"	"	34264
2917·0	1n		"	"	34272
2916·7	1		"	"	34275
2915·6	1		"	"	34288
2915·2	1		"	"	34293
2914·7	1		"	"	34299
2914·4	1		"	"	34302
2913·7	1		"	"	34311
2912·6	2		"	"	34324
2912·3	1		"	"	34327
2911·7	2		"	"	34333
2910·5	2		"	"	34358
2909·3	1		"	"	34363
2908·6	2		"	"	34371
2908·3	1		"	"	34374
2907·6	1		"	"	34383
2907·4	1		"	"	34385
2906·5	2		"	"	34396
2905·7	1		"	"	34405
2905·3	1		"	"	34410
2905·0	1		"	"	34413
2904·7	1		"	"	34417
2904·3	2		"	"	34422
2903·7	2		0·82	"	34429
2902·7	1		"	"	34441
2902·3	1		"	"	34445
2901·8	1		"	"	34451
2901·3	2		"	"	34457
2901·0	1		"	"	34461
2900·2	1		"	"	34470
2899·0	1		"	"	34485
2898·7	1		"	"	34488
2898·4	1		"	"	34492
2897·7	1		"	"	34500
2897·3	1		"	"	34505
2896·5	2		"	10·0	34514
2896·1	2		"	"	34519
2895·0	1		"	"	34532
2894·3	1		"	"	34541
2893·8	1		"	"	34547
2893·6	1		"	"	34549

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2893·1	1		0·82	10·0	34555
2893·0	1		,,	,,	34556
2892·6	1		,,	,,	34561
2892·2	1		,,	,,	34566
2891·6	1		,,	,,	34573
2891·1	1		,,	,,	34579
2890·7	1		,,	,,	34584
2889·9	2		,,	,,	34593
2889·5	1		,,	,,	34598
2888·8	1		,,	,,	34606
2888·4	1		,,	,,	34611
2887·7	1		,,	,,	34620
2887·0	2		,,	,,	34628
2886·5	1		,,	,,	34634
2885·8	1		,,	,,	34642
2885·6	1		,,	,,	34645
2885·0	1		,,	,,	34652
2884·3	2		,,	,,	34660
2883·3	1		,,	,,	34672
2882·5	2		,,	,,	34682
2881·7	2		,,	,,	34692
2880·8	1		,,	,,	34703
2880·3	1		,,	,,	34709
2879·6	1		,,	,,	34717
2879·3	1 Mo		,,	,,	34721
2878·4	1		,,	,,	34732
2878·3	1		,,	,,	34733
2877·1	1		,,	,,	34747
2876·3	1		,,	,,	34757
2876·1	1		,,	,,	34759
2875·6	1		,,	,,	34765
2875·3	1		,,	,,	34769
2874·7	1		,,	,,	34776
2874·0	1		,,	,,	34785
2873·5	1		,,	,,	34791
2872·8	1		,,	10·1	34799
2872·0	1		,,	,,	34809
2871·5	1		,,	,,	34815
2871·0	1		,,	,,	34821
2870·8	1		,,	,,	34823
2869·7	1		,,	,,	34837
2868·7	2		,,	,,	34849
2868·0	1		,,	,,	34857
2867·8	1		,,	,,	34860
2867·5	1		,,	,,	34864
2866·8	1		,,	,,	34872
2866·7	1		,,	,,	34873
2866·5	1		,,	,,	34876
2866·2	1		,,	,,	34879
2865·9	1		,,	,,	34883
2865·5	1		,,	,,	34888
2865·0	1		,,	,,	34894
2864·7	1		0·81	,,	34898
2864·2	1		,,	,,	34904
2863·7	1		,,	,,	34910

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2863·3	1		0·81	10·1	34915
2862·6	1		,,	,,	34923
2862·3	1		,,	,,	34927
2861·6	1		,,	,,	34935
2861·3	1		,,	,,	34939
2861·1	1		,,	,,	34942
2860·3	1		,,	,,	34951
2859·6	1		,,	,,	34960
2858·7	1		,,	,,	34971
2858·5	1		,,	,,	34973
2858·2	1		,,	,,	34977
2857·8	1		,,	,,	34982
2857·7	1		,,	,,	34983
2857·3	1		,,	,,	34988
2856·2	2		,,	,,	35002
2855·6	2		,,	,,	35009
2854·9	1		,,	,,	35017
2854·6	1		,,	,,	35021
2853·6	2		,,	,,	35033
2852·3	2		,,	,,	35049
2851·1	1		,,	,,	35064
2850·9	1		,,	,,	35067
2849·7	1		,,	,,	35081
2848·3	1		,,	10·2	35099
2848·2	1		,,	,,	35100
2848·0	1		,,	,,	35102
2847·4	1		,,	,,	35110
2847·3	2		,,	,,	35111
2846·3	1		,,	,,	35123
2845·8	1		,,	,,	35130
2845·1	1		,,	,,	35138
2844·7	1		,,	,,	35143
2843·9	1n		,,	,,	35153
2842·8	1		,,	,,	35167
2842·7	1		,,	,,	35168
2841·7	2		,,	,,	35180
2841·2	1		,,	,,	35186
2840·8	1		,,	,,	35191
2840·0	2		,,	,,	35201
2839·0	1		,,	,,	35214
2838·6	1n		,,	,,	35219
2837·9	1		,,	,,	35227
2837·5	1		,,	,,	35232
2837·0	1		,,	,,	35238
2836·3	1		,,	,,	35247
2835·8	1		,,	,,	35253
2835·3	1n		,,	,,	35260
2834·3	2		,,	,,	35272
2833·7	2		,,	,,	35280
2833·3	1		,,	,,	35285
2833·2	1		,,	,,	35286
2832·6	1		,,	,,	35293
2832·0	1		,,	,,	35301
2831·4	2		,,	,,	35308
2830·2	2		,,	,,	35323

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2830·0	1		0·81	10·2	35326
2828·7	1n		,,	,,	35342
2827·5	2		,,	,,	35357
2826·6	2		,,	,,	35368
2825·3	1		,,	,,	35384
2825·0	1n		,,	,,	35388
2824·3	1n		0·80	,,	35397
2823·9	1n		,,	10·3	35402
2822·6	2		,,	,,	35418
2821·7	1		,,	,,	35430
2820·7	2		,,	,,	35442
2820·0	2		,,	,,	35451
2819·2	2		,,	,,	35464
2818·2	2		,,	,,	35474
2817·5	1n		,,	,,	35482
2816·3	2		,,	,,	35498
2815·5	1		,,	,,	35508
2814·9	2		,,	,,	35515
2814·3	1n		,,	,,	35523
2813·3	2		,,	,,	35535
2812·3	2		,,	,,	35548
2810·0	2		,,	,,	35577
2809·0	2		,,	,,	35590
2808·0	1		,,	,,	35603
2807·9	1 Mo		,,	,,	35604
2806·7	1		,,	,,	35619
2806·1	2		,,	,,	35627
2805·7	1		,,	,,	35632
2805·2	1		,,	,,	35638
2804·9	1		,,	,,	35642
2804·7	1		,,	,,	35644
2804·3	1		,,	,,	35650
2804·0	1		,,	,,	35653
2803·7	2		,,	,,	35657
2803·3	1		,,	,,	35662
2803·1	1		,,	,,	35665
2802·7	1		,,	,,	35670
2802·5	1		,,	,,	35672
2802·2	1		,,	,,	35676
2801·6	1		,,	,,	35684
2801·3	2		,,	,,	35688
2800·2	1		,,	,,	35702
2799·22	4		,,	10·4	35713·8
2798·5	1n		,,	,,	35723
2797·6	1n		,,	,,	35735
2797·1	1n		,,	,,	35741
2796·3	1		,,	,,	35752
2795·7	2		,,	,,	35759
2793·8	1		,,	,,	35784
2793·2	1		,,	,,	35791
2792·8	1		,,	,,	35796
2792·0	1		,,	,,	35807
2791·9	1		,,	,,	35808
2790·6	2		,,	,,	35825
2790·3	1		,,	,,	35828

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2789·3	2		0·80	10·4	35841
2788·7	1		,,	,,	35849
2788·2	1		,,	,,	35855
2786·5	2		,,	,,	35877
2785·8	2		,,	,,	35886
2785·3	1		,,	,,	35893
2784·4	1		,,	,,	35904
2784·2	1		,,	,,	35907
2783·9	1		0·79	,,	35911
2783·3	1		,,	,,	35919
2782·7	1		,,	,,	35926
2782·3	2		,,	,,	35931
2780·5	2		,,	,,	35955
2779·5	1		,,	,,	35968
2778·8	2		,,	,,	35977
2778·1	1		,,	,,	35986
2777·7	1		,,	,,	35991
2776·7	2		,,	,,	36004
2775·2	1		,,	10·5	36022
2774·7	2		,,	,,	36029
2774·2	1		,,	,,	36035
2772·8	1		,,	,,	36054
2771·2	1		,,	,,	36074
2770·7	1		,,	,,	36081
2770·2	1		,,	,,	36087
2770·0	1		,,	,,	36090
2769·2	1		,,	,,	36101
2768·5	2		,,	,,	36110
2768·2	1		,,	,,	36114
2767·7	1		,,	,,	36120
2767·2	2		,,	,,	36127
2766·5	2		,,	,,	36136
2765·5	1		,,	,,	36149
2765·0	2		,,	,,	36155
2764·40	4		,,	,,	36163·7
2762·7	1n		,,	,,	36185
2761·6	2		,,	,,	36200
2760·8	1		,,	,,	36210
2760·6	1		,,	,,	36213
2759·6	1		,,	,,	36226
2759·5	1		,,	,,	36227
2757·9	1		,,	,,	36248
2757·3	1		,,	,,	36256
2756·8	1		,,	,,	36263
2755·1	1		,,	,,	36285
2753·3	2		,,	,,	36309
2753·2	1		,,	,,	36310
2751·6	1		,,	,,	36331
2750·8	1		,,	10·6	36342
2750·4	1		,,	,,	36347
2750·2	1		,,	,,	36350
2749·4*	2		,,	,,	36361
2749·0	1		,,	,,	36366

* Double.

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
2748·4	2		0·79	10·6	36374
2747·0	1		„	„	36392
2746·9	1		„	„	36394
2746·5	2		„	„	36399
2745·1	1		„	„	36418
2743·3	1		„	„	36441
2743·2	1		„	„	36443
2743·0	2		„	„	36445
2742·6	2		„	„	36451
2742·1	1		„	„	36457
2741·3	1		0·78	„	36468
2741·0	2		„	„	36472
2740·3	1		„	„	36481
2739·7	2n		„	„	36489
2738·6	1n		„	„	36504
2737·9	1n		„	„	36513
2737·0	1		„	„	36525
2736·7	1		„	„	36529
2735·9	1n		„	„	36540
2734·8	2		„	„	36555
2733·4	1		„	„	36573
2732·0	1		„	„	36592
2731·2	1n		„	„	36603
2730·9	1n		„	„	36607
2730·0	1		„	„	36619
2729·3	1		„	„	36628
2729·0	1		„	„	36632
2728·5	1		„	„	36639
2728·1	1n		„	„	36645
2727·7	1		„	„	36650
2726·7	2		„	10·7	36663
2725·5	1		„	„	36680
2725·2	1		„	„	36684
2724·5	1		„	„	36693
2722·8	2		„	„	36716
2721·7	1		„	„	36731
2720·6	2n		„	„	36746
2719·9	1		„	„	36755
2719·0	1		„	„	36767
2718·1	2		„	„	36779
2717·2	1		„	„	36792
2716·9	1		„	„	36796
2716·4	2		„	„	36802
2715·4	2		„	„	36816
2714·5	1n		„	„	36828
2714·0	1		„	„	36835
2713·5	1n		„	„	36842
2712·7	2n		„	„	36853
2711·8	1		„	„	36865
2710·9	2		„	„	36877
2710·4	1		„	„	36884
2709·7	1		„	„	36893
2708·9	1		„	„	36904
2708·7	2		„	„	36907
2707·8	1		„	„	36919

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2707·1	1n		0·78	10·7	36929
2706·8	2		,,	,,	36933
2706·0	1		,,	,,	36944
2705·8	1		,,	,,	36947
2703·6	2		,,	,,	36977
2703·2	2		,,	10·8	36982
2702·22	4		,,	,,	36995·8
2701·6	2		,,	,,	37004
2700·6	2		,,	,,	37018
2700·3	1		,,	,,	37022
2699·4	2b		,,	,,	37034
2698·6	1		0·77	,,	37045
2698·1	2		,,	,,	37052
2697·80	4		,,	,,	37056·4
2696·0	1n		,,	,,	37081
2695·1	1n		,,	,,	37093
2694·7	2		,,	,,	37099
2694·6	2		,,	,,	37100
2694·2	1		,,	,,	37106
2692·7	1n		,,	,,	37126
2692·0	1n		,,	,,	37136
2691·2	2		,,	,,	37147
2689·2	1		,,	,,	37175
2688·4	2		,,	,,	37186
2687·7	1		,,	,,	37196
2687·2	2		,,	,,	37202
2686·6	1		,,	,,	37211
2685·5	1		,,	,,	37226
2685·3	1		,,	,,	37229
2684·6	1		,,	,,	37238
2683·8	2		,,	,,	37250
2683·4	2		,,	,,	37255
2681·7	1		,,	,,	37279
2680·8	1		,,	,,	37291
2679·78	4		,,	,,	37305·7
2679·2	1		,,	10·9	37314
2678·1	2		,,	,,	37329
2676·5	1		,,	,,	37351
2676·1	2		,,	,,	37357
2675·4	1		,,	,,	37367
2674·9	1		,,	,,	37374
2674·3	1		,,	,,	37382
2673·2	1		,,	,,	37397
2672·9	1		,,	,,	37402
2671·7	1		,,	,,	37418
2670·6	2		,,	,,	37434
2669·5	2		,,	,,	37449
2668·2	1		,,	,,	37467
2667·9	1		,,	,,	37472
2666·7	2		,,	,,	37489
2666·2	2		,,	,,	37496
2665·9	1n		,,	,,	37500
2665·2	1		,,	,,	37510
2664·41	4		,,	,,	37520·9
2664·1	1		,,	,,	37525

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2663·7	1		0·77	10·9	37531
2663·0	1		,,	,,	37541
2662·4	1		,,	,,	37549
2661·8	1n		,,	,,	37558
2660·8	1		,,	,,	37572
2659·9	1		,,	,,	37584
2659·4	1		,,	,,	37591
2658·10	4		,,	,,	37609·0
2658·0	1		,,	,,	37611
2657·5	1		,,	,,	37618
2656·7	1		,,	,,	37630
2656·2	1		,,	,,	37637
2655·7	1		,,	,,	37644
2654·7	1		0·76	11·0	37658
2654·5	1		,,	,,	37661
2653·7	2		,,	,,	37672
2652·1	2		,,	,,	37695
2651·5	1		,,	,,	37703
2651·1	1		,,	,,	37709
2650·4	1		,,	,,	37719
2650·0	1		,,	,,	37725
2649·8	1		,,	,,	37728
2647·81	4		,,	,,	37750·1
2646·9	1		,,	,,	37769
2646·2	1		,,	,,	37779
2645·7	1		,,	,,	37786
2644·7	1		,,	,,	37800
2644·1	1		,,	,,	37809
2643·3	2		,,	,,	37820
2643·1	2		,,	,,	37823
2641·1	1		,,	,,	37852
2639·6	1		,,	,,	37874
2639·2	1		,,	,,	37879
2638·7	1		,,	,,	37886
2638·3	1		,,	,,	37892
2637·2	1		,,	,,	37908
2636·7	1n		,,	,,	37915
2635·4	2		,,	,,	37934
2634·9	1		,,	,,	37941
2634·0	2		,,	,,	37954
2633·2	1		,,	,,	37966
2632·9	1		,,	,,	37970
2631·4	2		,,	11·1	37992
2630·4	1		,,	,,	38006
2629·6	1n		,,	,,	38018
2629·1	2		,,	,,	38025
2628·3	1		,,	,,	38036
2628·1	1		,,	,,	38039
2627·8	1		,,	,,	38044
2626·9	1n		,,	,,	38057
2626·5	1		,,	,,	38062
2626·3	1		,,	,,	38065
2625·7	1n		,,	,,	38074
2625·2	1n		,,	,,	38081
2624·0	1		,,	,,	38099

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2622·9	1		0·76	11·1	38115
2622·3	2n		"	"	38123
2621·7	2		"	"	38132
2620·8	2		"	"	38145
2620·25	4		"	"	38153·2
2619·2	1		"	"	38169
2618·0	1		"	"	38186
2617·2	1		"	"	38198
2616·7	1		"	"	38205
2615·48	4		"	"	38222·8
2614·4	1n		"	"	38239
2613·8	2		"	"	38247
2613·1	1		"	"	38258
2612·8	2		"	"	38262
2611·9	2		"	"	38275
2611·4	1		"	"	38283
2610·7	1		"	"	38293
2610·3	1		"	"	38299
2609·2	1		0·75	11·2	38315
2608·4	1		"	"	38327
2607·1	2		"	"	38346
2606·5	2		"	"	38355
2606·4	1		"	"	38356
2605·9	1		"	"	38363
2605·5	1		"	"	38369
2604·5	1		"	"	38384
2604·2	1		"	"	38389
2603·6	1		"	"	38397
2603·07	4		"	"	38405·0
2602·58	4		"	"	38412·2
2602·1	1		"	"	38420
2601·5	2		"	"	38428
2601·2	1		"	"	38433
2600·9	1		"	"	38437
2599·7	2 Fe		"	"	38455
2598·9	2		"	"	38467
2598·5	2		"	"	38473
2597·9	2		"	"	28482
2596·9	1		"	"	38496
2596·2	1n		"	"	38507
2595·6	1		"	"	38516
2594·9	1		"	"	38526
2593·8	1		"	"	38542
2593·4	1		"	"	38548
2592·9	1		"	"	38556
2592·6	1		"	"	38560
2591·5	1		"	"	38577
2589·7	1		"	"	38604
2589·20	4		"	"	38610·8
2588·5	1		"	11·3	38621
2587·9	1		"	"	38630
2587·5	1		"	"	38636
2587·2	1		"	"	38641
2586·6	1		"	"	38650
2586·3	1		"	"	38654

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2585·7	1		0·75	11·3	38663
2585·1	1		,,	,,	38672
2584·2	2		,,	,,	38686
2583·3	1		,,	,,	38699
2582·5	1		,,	,,	38711
2582·3	1		,,	,,	38714
2581·22	4		,,	,,	38730·1
2580·3	1		,,	,,	38744
2579·8	1		,,	,,	38752
2579·60	4		,,	,,	38754·4
2579·32	4		,,	,,	38758·6
2578·7	1		,,	,,	38768
2578·2	1		,,	,,	38776
2577·8	1		,,	,,	38782
2577·5	1		,,	,,	38786
2577·2	1		,,	,,	38791
2576·7	1		,,	,,	38798
2576·2	2		,,	,,	38806
2576·0	2		,,	,,	38809
2574·9	1n		,,	,,	38825
2574·1	1n		,,	,,	38838
2573·8	1		,,	,,	38842
2573·4	1		,,	,,	38848
2573·2	1		,,	,,	38851
2572·7	1		,,	,,	38859
2572·4	1		,,	,,	38863
2572·30	4		,,	,,	38864·4
2571·45	4		,,	,,	38877·3
2569·8	1		,,	,,	38903
2568·7	2		,,	11·4	38919
2567·8	1		,,	,,	38933
2567·7	1		,,	,,	38934
2567·4	2		,,	,,	38939
2566·8	1		,,	,,	38948
2566·6	1		,,	,,	38951
2566·2	1		,,	,,	38957
2565·7	1		,,	,,	38965
*2564·4	1n		0·74	,,	38984
2563·7	2		,,	,,	38995
2563·4	1		,,	,,	39000
2563·22	4		,,	,,	39002·0
2562·5	2		,,	,,	39013
2562·2	1		,,	,,	39018
2561·9	1		,,	,,	39023
2561·5	1		,,	,,	39029
2560·7	1		,,	,,	39041
2559·9	1		,,	,,	39053
2559·4	2		,,	,,	39061
2557·9	2		,,	,,	39084
2557·4	1		,,	,,	39091
2557·1	1		,,	,,	39096
2556·9	1		,,	,,	39099
2556·6	1		,,	,,	39103

* Double.

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
2555·9	1		0·74	11·4	39114
2555·13	4		"	"	39125·5
2554·8	2		"	"	39131
2554·6	2		"	"	39134
2553·7	1		"	"	39148
2553·1	2		"	"	39157
2552·2	2		"	"	39171
2552·0	1		"	"	39174
2551·3	2		"	"	39185
2551·0	1		"	"	39189
2550·1	1		"	"	39203
2549·9	1		"	"	39206
2548·9	1		"	11·5	39222
2548·7	1		"	"	39224
2548·4	2		"	"	39228
2547·8	1		"	"	39238
2547·0	1		"	"	39250
2546·2	2		"	"	39262
2545·3	1		"	"	39276
2544·7	2		"	"	39285
2543·9	1		"	"	39298
2543·3	2		"	"	39307
2541·6	1n		"	"	39333
2541·4	1		"	"	39336
2540·9	2n		"	"	39344
2539·8	2		"	"	39361
2539·2	2		"	"	39370
2538·9	1		"	"	39375
2538·8	1		"	"	39377
2538·2	1		"	"	39386
2537·5	1		"	"	39397
2536·6	1		"	"	39411
2536·4	2		"	"	39414
2535·5	1		"	"	39428
2534·7	2		"	"	39440
2534·0	2		"	"	39451
2533·5	1		"	"	39459
2533·1	1		"	"	39465
2532·8	1		"	"	39470
2532·7	1		"	"	39472
2532·2	1		"	"	39479
2531·9	1		"	"	39484
2530·9	2		"	"	39500
2530·6	1		"	"	39504
2529·7	1		"	11·6	39518
2529·6	1		"	"	39520
2529·2	1		"	"	39526
2529·0	2		"	"	39529
2528·6	2		"	"	39536
2528·2	1		"	"	39542
2527·7	1		"	"	39550
2526·2	2		"	"	39573
2525·7	1		"	"	39581
2525·5	1		"	"	39584
2525·0	1		"	"	39592

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark-Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2524·8	1		0·74	11·6	39595
2524·1	2		,,	,,	39606
2523·5	1		,,	,,	39615
2523·4	1		,,	,,	39617
2522·9	1		,,	,,	39625
2522·8	1		,,	,,	39626
2522·08	4		,,	,,	39637·2
2521·1	1		,,	,,	39653
2520·4	1		,,	,,	39664
2520·0	1		,,	,,	39671
2519·0	1		,,	,,	39686
2518·6	1		,,	,,	39693
2518·1	2		,,	,,	39700
2517·3	2		0·73	,,	39713
2517·0	1		,,	,,	39718
2516·1	2		,,	,,	39732
2515·7	1		,,	,,	39738
2515·3	2		,,	,,	39745
2514·4	2		,,	,,	39759
2514·3	2		,,	,,	39761
2513·9	2		,,	,,	39767
2513·2	2		,,	,,	39778
2512·7	2		,,	,,	39786
2512·1	1		,,	,,	39795
2511·7	1		,,	11·7	39802
2511·3	1		,,	,,	39808
2510·9	1		,,	,,	39814
2510·52	4		,,	,,	39820·7
2509·9	1		,,	,,	39830
2509·6	1		,,	,,	39835
2508·6	1		,,	,,	39851
2507·9	1 C?		,,	,,	39862
2507·1	1		,,	,,	39875
2506·8	1		,,	,,	39879
2506·0	2		,,	,,	39892
2505·5	1n		,,	,,	39900
2504·7	1n		,,	,,	39913
2503·6	1n		,,	,,	39930
2502·0	1		,,	,,	39956
2501·8	1		,,	,,	39959
2501·0	1		,,	,,	39972
2500·8	1		,,	,,	39975
2500·1	2		,,	,,	39986
2499·7	1		,,	,,	39993
2499·2	2		,,	,,	40001
2498·9	1		,,	,,	40006
2498·2	1n		,,	,,	40017
2497·5	2		,,	,,	40028
2496·6	2		,,	,,	40042
2495·5	1		,,	,,	40060
2495·3	1		,,	,,	40063
2494·9	1		,,	,,	40070
2494·1	1n		,,	11·8	40083
2492·9	2		,,	,,	40102
2492·3	2		,,	,,	40112

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2491·7	1		0·73	11·8	40121
2490·6	2		"	"	40139
2490·2	1		"	"	40145
2489·9	1		"	"	40150
2489·35	4		"	"	40159·3
2488·92	4		"	"	40166·3
2488·2	2		"	"	40178
2487·5	1		"	"	40189
2487·3	1		"	"	40192
2486·3	1n		"	"	40208
2485·6	1n		"	"	40220
2484·7	1n		"	"	40234
2484·3	2		"	"	40241
2484·0	1		"	"	40246
2483·6	2 C		"	"	40252
2482·1	2		"	"	40276
2481·6	2		"	"	40285
2480·9	1		"	"	40296
2480·2	2		"	"	40307
2479·1	1		"	"	40325
2478·9	1		"	"	40328
2478·7	1		"	"	40332
2478·3	1		"	"	40338
2477·93	4		"	"	40344·5
2477·2	2		"	"	40356
2476·6	1n		"	11·9	40366
2475·7	1		"	"	40381
2475·6	2		"	"	40382
2474·3	1		"	"	40403
2474·2	1		"	"	40405
2473·9	1n		"	"	40410
2473·2	1		"	"	40421
2472·4	1		"	"	40435
2471·7	2		"	"	40446
2470 9	1		"	"	40459
2469·9	2		0·72	"	40475
2469·2	1		"	"	40487
2468·4	2		"	"	40500
2467·4	1		"	"	40516
2466·5	2		"	"	40531
2465·9	1		"	"	40541
2465·6	2		"	"	40546
2465·2	1		"	"	40553
2464·6	2		"	"	40563
2464·2	1		"	"	40569
2464·0	1		"	"	40572
2463·2	2		"	"	40586
2462·8	1		"	"	40592
2462·3	1		"	"	40600
2461·9	1		"	"	40607
2461·4	2		"	"	40615
2461·2	2		"	"	40619
2460·4	1n		"	"	40632
2459·8	1		"	12·0	40642
2459·6	1		"	"	40645

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
2459·2	1		0·72	12·0	40652
2458·7	2		,,	,,	40660
2458·5	2		,,	,,	40663
2457·1	2		,,	,,	40686
2456·5	1		,,	,,	40696
2456·1	1		,,	,,	40703
2455·9	2		,,	,,	40706
2454·9	1		,,	,,	40723
2454·8	1		,,	,,	40725
2453·8	1		,,	,,	40741
2452·9	1		,,	,,	40756
2452·0	1		,,	,,	40771
2450·3	1		,,	,,	40799
2449·7	2		,,	,,	40809
2448·6	1		,,	,,	40828
2448·2	2		,,	,,	40834
2447·2	1		,,	,,	40851
2446·50	4		,,	,,	40862·7
2445·5	1		,,	,,	40879
2444·9	1		,,	,,	40889
2444·6	1		,,	,,	40894
2444·2	1		,,	,,	40901
2441·6	1		,,	12·1	40945
2441·4	1		,,	,,	40948
2439·9	1		,,	,,	40973
2439·4	1		,,	,,	40982
2438·3	1		,,	,,	41000
2437·4	2		,,	,,	41015
2436·6	1		,,	,,	41029
2435·9	1		,,	,,	41041
2435·4	1		,,	,,	41049
2435·0	2		,,	,,	41056
2434·4	1		,,	,,	41066
2434·2	1		,,	,,	41069
2433·1	1		,,	,,	41088
2432·9	1		,,	,,	41091
2432·2	1		,,	,,	41103
2431·6	1		,,	,,	41113
2430·7	1		,,	,,	41128
2429·8	1n		,,	,,	41144
2428·7	1		,,	,,	41162
2428·3	1		,,	,,	41169
2427·8	1		,,	12·2	41178
2427·5	2		,,	,,	41183
2426·6	1		,,	,,	41198
2425·9	1n		,,	,,	41210
2424·9	1		,,	,,	41227
2424·6	1		,,	,,	41232
2424·1	1		,,	,,	41240
2423·9	1		,,	,,	41244
2423·3	1		,,	,,	41254
2422·5	1		,,	,,	41268
2422·3	1		,,	,,	41271
2421·1	2		0·71	,,	41292
2420·6	2		,,	,,	41300

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2420·0	1n		0·71	12·2	41310
2419·4	2		,,	,,	41321
2418·2	1		,,	,,	41341
2417·9	1		,,	,,	41346
2417·6	2		,,	,,	41351
2416·0	1		,,	,,	41379
2415·7	1		,,	,,	41384
2414·8	2		,,	,,	41399
2414·2	1		,,	,,	41410
2413·3	1		,,	,,	41425
2412·8	1		,,	12·3	41434
2411·9	1		,,	,,	41449
2411·6	1		,,	,,	41454
2411·4	1		,,	,,	41458
2411·2	1		,,	,,	41460
2410·5	2		,,	,,	41473
2409·5	1		,,	,,	41490
2409·3	1		,,	,,	41494
2408·3	2		,,	,,	41511
2407·8	2		,,	,,	41520
2407·2	1		,,	,,	41530
2406·6	1		,,	,,	41540
2406·3	1		,,	,,	41546
2406·0	1		,,	,,	41551
2405·6	1		,,	,,	41558
2405·3	1		,,	,,	41563
2404·9	2		,,	,,	41570
2404·3	2		,,	,,	41580
2403·4	1		,,	,,	41596
2402·4	1		,,	,,	41614
2399·9	1		,,	,,	41656
2399·2	1 Fe		,,	,,	41669
2398·1	2		,,	12·4	41688
2397·12	4		,,	,,	41704·3
2396·2	1		,,	,,	41721
2395·6	2		,,	,,	41731
2395·4	1		,,	,,	41735
2395·1	1		,,	,,	41740
2394·4	1		,,	,,	41752
2393·2	1		,,	,,	41773
2393·0	2		,,	,,	41777
2391·8	1		,,	,,	41798
2391·2	1		,,	,,	41808
2390·9	1		,,	,,	41813
2390·4	2		,,	,,	41822
2389·8	2		,,	,,	41833
2389·3	1		,,	,,	41841
2388·8	1		,,	,,	41850
2388·6	1		,,	,,	41854
2387·7	1n		,,	,,	41869
2386·5	1		,,	,,	41890
2386·2	1		,,	,,	41896
2385·5	1		,,	,,	41908
2385·3	2		,,	,,	41911
2383·5	1		,,	,,	41943

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda +$	$\frac{1}{\lambda} -$	
2382·7	1		0·71	12·5	41956
2382·4	1		,,	,,	41961
2382·0	1		,,	,,	41969
2381·8	1		,,	,,	41972
2381·4	1		,,	,,	41979
2381·2	1		,,	,,	41983
2380·9	1		,,	,,	41988
2380·4	1		,,	,,	41997
2380·3	1		,,	,,	41999
2379·7	1		,,	,,	42009
2378·2	1		,,	,,	42036
2377·1	1		,,	,,	42055
2375·9	1		,,	,,	42076
2374·5	2		,,	,,	42101
2373·7	1		0·70	,,	42115
2373·4	1		,,	,,	42121
2372·7	2		,,	,,	42133
2371·9	1		,,	,,	42147
2371·1	1		,,	,,	42162
2370·1	2		,,	,,	42179
2369·0	1		,,	,,	42199
2368·4	2		,,	12·6	42210
2367·8	1		,,	,,	42220
2367·2	1		,,	,,	42231
2366·7	1		,,	,,	42240
2365·9	1		,,	,,	42254
2365·5	1		,,	,,	42261
2364·4	2		,,	,,	42281
2364·1	1		,,	,,	42286
2363·5	1		,,	,,	42297
2362·2	2		,,	,,	42320
2361·7	1		,,	,,	42329
2361·3	1		,,	,,	42337
2359·4	1		,,	,,	42371
2358·9	2		,,	,,	42380
2358·1	1		,,	,,	42394
2357·4	1		,,	,,	42407
2356·9	1		,,	,,	42416
2353·7	1		,,	12·7	42473
2353·5	1		,,	,,	42477
2351·6	1		,,	,,	42511
2351·3	1		,,	,,	42517
2350·4	1		,,	,,	42533
2349·9	1		,,	,,	42542
2349·4	2		,,	,,	42551
2348·2	2b		,,	,,	42573
2346·5	1		,,	,,	42604
2345·0	1		,,	,,	42631
2344·5	1		,,	,,	42640
2343·7	2		,,	,,	42655
2341·4	1		,,	,,	42696
2339·7	1		,,	12·8	42728
2339·1	1		,,	,,	42738
2337·7	1		,,	,,	42764
2336·8	1		,,	,,	42781

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
2336·0	1		0·70	12·8	42795
2335·2	1		„	„	42810
2334·7	1		„	„	42819
2333·9	2		„	„	42834
2333·2	1		„	„	42847
2332·2	1		„	„	42865
2331·6	1		„	„	42876
2330·6	1		„	„	42894
2329·5	1		„	„	42915
2328·4	1		„	„	42935
2327 6	1n		„	12·9	42950
2326·7	1n		„	„	42966
2326·0	2		„	„	42979
2324·7	1		0·69	„	43003
2324·0	1		„	„	43016
2323·1	2		„	„	43033
2321·0	1		„	„	43072
2319·0	1		„	„	43109
2318·0	1		„	„	43128
2314·7	1		„	„	43189
2314·2	1		„	13·0	43198
2313·0	1		„	„	43221
2310·7	1		„	„	43264
2309·9	1		„	„	43279
2307·1	1		„	„	43331
2305·8	1		„	„	43356
2302·7	1		„	„	43414
2301·9	1		„	„	43429
2300·5	1		„	13·1	43456
2299·4	1n		„	„	43477
2298·9	1		„	„	43486
2298·5	1		„	„	43494
2297·2	1n C?		„	„	43518
2295·7	1		„	„	43547
2294·3	1		„	„	43573
2293·2	1		„	„	43594
2291·6	1n		„	„	43625
2290·8	1		„	„	43640
2288·8	1		„	„	43678
2284·8	1n		„	13·2	43755
2284·1	1n		„	„	43768
2283·4	1n		„	„	43781
2282·1	1		„	„	43806
2281·4	1		„	„	43820
2281·1	1		„	„	43825
2280·7	1		„	„	43833
2278·3	1		„	„	43879
2277·9	1		0·68	„	43887
2275·3	1		„	13·3	43937
2272·7	1n		„	„	43988
2270·5	1		„	„	44030
2266·5	1		„	„	44108
2264·6	1		„	„	44145
2263·3	1		„	13·4	44170
2262·6	1		„	„	44184

TUNGSTEN (SPARK SPECTRUM)—*continued.*

Wave-length Spark Spectrum (Rowland)	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
2260·3	1		0·68	13·4	44229
2259·4	1		,,	,,	44247
2258·4	1		,,	,,	44266
2257·4	1		,,	,,	44286
2256·7	1		,,	,,	44299
2255·2	1		,,	,,	44329
2251·6	1		,,	,,	44400
2250·9	1		,,	13·5	44413
2250·2	1		,,	,,	44426
2249·5	1		,,	,,	44440
2248·7	1		,,	,,	44456
2245·9	1		,,	,,	44512
2245·3	1		,,	,,	44523
2243·8	1		,,	,,	44553
2243·0	1n		,,	,,	44569
2241·4	1		,,	,,	44601
2240·2	1n		,,	,,	44625
2237·1	1		,,	13·6	44687
2235·6	1b		,,	,,	44717
2231·4	1		,,	,,	44801
2229·6	1		0·67	,,	44837
2227·0	1n		,,	,,	44889
2226·1	1n		,,	13·7	44908
2222·3	1		,,	,,	44984
2221·7	1		,,	,,	44997
2219·4	1		,,	,,	45043
2218·0	1		,,	,,	45072
2216·2	1		,,	,,	45108
2215·5	1		,,	,,	45123
2215·1	1		,,	13·8	45131
2208·7	1		,,	,,	45262
2206·7	1		,,	,,	45303
2204·4	1		,,	,,	45350
2201·1	1		,,	13·9	45418
2198·9	1		,,	,,	45463
2198·2	1		,,	,,	45478
2197·7	1		,,	,,	45488
2196·0	1		,,	,,	45523
2194·9	1		,,	,,	45546
2193·2	1		,,	,,	45581
2189·7	1		,,	14·0	45654
2186·7	1		,,	,,	45717
2186·0	1n		,,	,,	45732
2182·2	1		,,	,,	45811
2166·2	1		0·66	14·2	46150
2163·7	1		,,	,,	46203
2161·2	1n		,,	,,	46257
2153·7	1		,,	14·3	46418
2152·5	1		,,	,,	46444
2146·2	1		,,	14·4	46580

PLATINUM (SPARK AND ARC SPECTRA).

Kayser: 'Abhandl. königl. Akad. Wissensch. Berlin,' 1897.

Exner and Haschek: 'Sitz. kaiserl. Akad. Wissensch. Wien,' civ. (1895), cv. 1896, cvi. (1897).

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
	5861·074		2		1·60	4·6	17057·1
	5845·050		4	5845·1 Thalén	1·59	"	17103·9
	5840·354		5		"	"	17117·7
	5763·778		3		1·57	4·7	17345·0
	5762·877		3		"	"	17347·7
	5728·369		0		1·56	"	17452·3
	5700·672		0		1·55	4·8	17537·0
	5699·190		1		"	"	17541·6
	5684·908		2		"	"	17585·6
	5660·245		2		1·54	"	17662·3
	5626·077		4		1·53	"	17769·6
	5514·324		4		1·50	4·9	18129·7
	5478·722		6	5478·1 "	"	5·0	18247·4
	5475·996		6	5475·6 "	1·49	"	18256·5
	5469·714		2		"	"	18277·5
	5452·984		0		"	"	18333·6
	5391·010		4		1·47	5·1	18544·3
	5388·105		2	5389·6 "	"	"	18554·3
	5369·188		4	5367·6 "	"	"	18619·7
	5324·799		0		1·45	"	18774·9
	5319·540		0		"	"	18793·5
	5306·493		0		"	"	18839·8
	5301·182		6	5301·6 "	"	5·2	18858·5
	5295·918		0		"	"	18877·3
	5286·289		0n		1·44	"	18911·7
	5275·008		0n		"	"	18952·1
	5265·290		0		"	"	18987·1
	5260·982		3		"	"	19002·7
	5257·609		0n		"	"	19014·9
	5227·782		6	5226·2 "	1·43	"	19123·4
	5208·775		0		1·42	5·3	19200·4
	5194·050		1		"	"	19247·5
	5118·583		1		1·40	"	19531·4
	5095·950		0n		1·39	5·4	19618·0
	5059·658		5	5059·6 "	1·38	"	19758·8
	5050·006		1		"	"	19796·5
	5044·645		6		"	"	19817·6
	5044·194		4		"	"	19819·4
	5038·681		0		"	"	19841·1
	5037·859		0n		"	"	19844·3
	5033·686		4		"	"	19860·7
	5002·762		2		1·37	5·5	19983·5
	4998·123		2		"	"	20002·0
	4980·532		1		1·36	"	20072·7
	4879·700		4	4879·1 "	1·34	5·6	20487·5
	4862·577		0		1·33	"	20559·6
	4854·067		4		"	5·7	20595·6
	4831·371		0		1·32	"	20692·4
	4772·467		1		1·31	5·8	20947·7
	4746·046		1		1·30	"	21064·4
	4739·924		1		"	"	21091·6

NOTE.—In the arc spectrum the intensities are estimated on a scale from 0 to 10 : 0 denoting a very weak line.

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Angström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
	4737·722		2		1·30	5·8	21101·4
	4684·255		4		1·28	5·9	21342·2
	4658·105		5		”	”	21462·0
	4650·192		1		1·27	”	21498·6
4640·8 4640·5	4639·984	1	4		”	”	21545·9
	4580·828		2		1·25	6·0	21824·1
	4580·685		2		”	”	21824·8
4577·0	4577·584	1n	4		”	”	21839·6
4560·2	4560·209	1	4		”	6·1	21922·7
4558·9		1			”	”	21929
4554·8	*4554·759	1	4		”	”	21949·0
4554·3		2			”	”	21951
4552·62	*4552·586	4	5n	4551·9 Thalén	”	”	21959·4
	4552·116		2		”	”	21961·7
4548·0	4548·056	1	3n		”	”	21981·3
4546·3		1			”	”	21990
4523·2	4523·192	1	5n		1·24	”	22102·2
4521·2	4521·099	1	5n	4521 Huggins	”	”	22112·4
4514·3		1			”	”	22146
4511·3	4511·417	1	5n		”	”	22159·9
4510·9		1			”	”	22162
4505·0		1			1·23	”	22191
4498·93	*4498·926	4	6	4498·3 Thalén	”	”	22221·4
4495·0		1			”	6·2	22241
4493·4	4493·350	1	3		”	”	22249·0
4492·7		1			”	”	22252
4484·8	4484·882	1	5n		”	”	22290·9
4482·2		1			”	”	22304
4481·9	4481·808	1	3		”	”	22306·2
4473·7	4473·633	1	3n		”	”	22347·0
4471·8		1			”	”	22356
4458·9		1			1·22	”	22421
4457·2		1			”	”	22429
4453·3		1n			”	”	22449
4448·8		1			”	”	22472
4445·7	*4445·710	1	4		”	”	22487·4
4442·73	*4442·730	4	6	4442·1 ”	”	”	22502·5
4437·5	4437·470	1	4n		”	”	22529·2
	4414·420		2		1·21	6·3	22646·7
4411·5	4411·580	1n	3		”	”	22661·3
4410·9		1			”	”	22665
4409·0		1n			”	”	22675
4392·0	*4391·999	2	4	4389·5 ”	1·20	”	22762·4
4372·0		1			”	”	22866
4364·5	4364·624	1	4		”	6·4	22905·1
4358·5	4358·522	1n	2n		”	”	22937·2
4351·3		2n			1·19	”	22944
4347·0		1			”	”	22998
	4343·852		0		”	”	23014·7
4341·9		1			”	”	23025
4334·8	4334·827	1n	2		”	”	23062·6
4327·2	*4327·243	4	4	4327·0 ”	”	”	23103·0

* Rowland 4554·828, 4552·594, 4498·930, 4445·713, 4442·723, 4391·996, 4327·320.

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
4309·3		1n			1·18	6·4	23199
4291·2	4291·070	1	2	(Rowland)	,,	6·5	23298·5
4288·6	4288·215	1	4	4288·217 R.	,,	,,	23313·2
	4281·905		1		,,	,,	23347·6
4275·2		1			1·17	,,	23384
4274·2	4274·042	1	2		,,	,,	23390·6
4271·2		1n			,,	,,	23406
4269·7	4269·411	1n	2		,,	,,	23415·9
4263·8	4263·664	1n	2		,,	,,	23447·5
4260·1		1			,,	,,	23467
	4251·277		1		,,	6·6	23515·7
4247·8	4247·838	1n	1		,,	,,	23534·8
4226·85 Ca		4			1·16	,,	23661·7
4223·8		1			,,	,,	23669
4222·7		1			,,	,,	23675
4221·2		1			,,	,,	23683
4214·2		1			,,	,,	23723
4213·3		1			,,	,,	23728
4211·5		1			,,	,,	23738
4205·8		2n			1·15	,,	23770
4202·2		1			,,	,,	23790
4201·5	4201·374		2		,,	,,	23795·2
4194·5		1			,,	6·7	23834
4192·55	4192·577	4	4	·589 ,,	,,	,,	23845·0
4185·7		2n			,,	,,	23884
4170·5		1			,,	,,	23971
4167·5		1			1·14	,,	23988
4166·5		1			,,	,,	23994
4164·72	4164·709	4	4	·722 ,,	,,	,,	24004·6
4163·5		2n			,,	,,	24012
4159·0		1			,,	,,	24037
4148·5		1			,,	6·8	24098
4134·3		1			,,	,,	24181
4133·7		2n			,,	,,	24185
4132·5		1			,,	,,	24192
4129·7		1			1·13	,,	24208
4118·86	4118·854	6	5	·838 ,,	,,	,,	24271·8
4092·5	4092·426	1	3	·421 ,,	1·12	6·9	24428·5
4090·5		1			,,	,,	24440
4087·7		1			,,	,,	24457
	4081·631		1	·627 ,,	,,	,,	24493·1
4078·1		1			,,	,,	24514
4072·2		2			,,	,,	24550
4066·5	4066 087	1	2	·094 ,,	,,	,,	24586·8
4063·0		1			,,	,,	24605
4061·9		1			,,	,,	24612
4060·7		1n			,,	,,	24619
4055·0	4054·928	1	2	·925 ,,	1·11	,,	24654·4
4051·2		1			,,	7·0	24677
4050·2		1			,,	,,	24683
4046·55		4			,,	,,	24705·4
4034·3		1			,,	,,	24780
4024·0		1			,,	,,	24844
4021·4		1			,,	,,	24860
4014·3		1			1·10	,,	24904

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
4007·5		1			1·10	7·0	24946
4002·7	4002·649	1	2		,,	7·1	24976·3
3996·7	3996·720	1	3	·722 R.	,,	,,	25013·4
	3980·746		1		,,	,,	25113·8
3979·0		1n			,,	,,	25125
3976·5	3976·460	1	1		,,	,,	25140·9
3975·8		1			1·09	,,	25145
3972·0		1			,,	,,	25169
3971·3		1			,,	,,	25174
3970·1		2			,,	,,	25181
3969·3		1			,,	,,	25186
3968·5 Ca		6			,,	,,	25191
3966·48	3966·507	6	3	·504 ,,	,,	,,	25204·0
3961·7		1			,,	,,	25235
3958·0		1			,,	,,	25258
3953·1	3953·780	1n	1		,,	7·2	25285·0
3950·6		1n			,,	,,	25305
3948·4	3948·550	1	4	·539 ,,	,,	,,	25318·6
3931·0		1			1·08	,,	25432
3930·5		1			,,	,,	25435
3927·1		1			,,	,,	25457
3926·6		1			,,	,,	25460
3925·50	3925·483	4	4	·486 ,,	,,	,,	25467·4
3923·12	3923·105	8	5	·106 ,,	,,	,,	25482·8
3911·1	3911·045	1	3	·050 ,,	,,	,,	25561·4
3910·6		1			,,	,,	25564
3908·5		1			,,	7·3	25578
	3906·433		2		,,	,,	25591·5
3904·4	3904·534		3		,,	,,	25604·0
	3903·864		2		,,	,,	25608·4
3902·3		1			,,	,,	25619
3900·90	3900·873	4	4	·874 ,,	,,	,,	25628·0
3898·92	3898·880	4	4	·886 ,,	,,	,,	25641·1
3895·5		1			1·07	,,	25663
3894·9		1			,,	,,	25667
3892·0		1n			,,	,,	25688
3890·5		1n			,,	,,	25696
3889·2		1n			,,	,,	25705
3887·5		1			,,	,,	25716
3885·3		1n			,,	,,	25731
3884·3		1n			,,	,,	25737
3883·3		1n			,,	,,	25744
3881·1		1n			,,	,,	25759
3875·83		4			,,	,,	25793·6
3873·7		1n			,,	,,	25808
3868·60		4			,,	,,	25842
3863·3		1			,,	,,	25877
3856·5		1			1·06	,,	25923
3854·8		1n			,,	,,	25934
3852·7		1			,,	,,	25948
3847·6		1n			,,	,,	25983
3845·3		1			,,	,,	25998
3843·8		1			,,	,,	26009
3838·3		2			,,	,,	26046
3837·8		1n			,,	,,	26049

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
3835·2		1n			1·06	7·3	26067
3833·1		1			,,	,,	26081
3829·5		1			,,	,,	26106
3827·2		1			,,	,,	26121
3818·82	3818·827	6	5	·827 R.	,,	,,	26178·7
3815·3		2			1·05	7·4	26203
3808·4					,,	,,	26250
3807·2					,,	,,	26259
3805·6		1			,,	,,	26270
3803 3		1n			,,	,,	26286
3802·6		1			,,	,,	26290
3801·3					,,	,,	26299
3798·2		1			,,	,,	26321
3791·8		1n			,,	,,	26365
3789·8		1			,,	,,	26379
3788·8		1			,,	,,	26386
3785·3		1n			,,	,,	26411
3776·7		1n			1·04	,,	26471
3775·0		1n			,,	,,	26483
3771·3		1n			,,	7·5	26509
3770·3		1n			,,	,,	26516
3768·7					,,	,,	26527
3767·5		2			,,	,,	26535
3766·7					,,	,,	26541
3764·1		2			,,	,,	26559
3761·4		1n			,,	,,	26578
3754·8		1			,,	,,	26625
3750·0					,,	,,	26659
3749·0		1			,,	,,	26666
3747·4		1			,,	,,	26678
3746·2		1			,,	,,	26686
3743·8		1			,,	,,	26703
3740·6		1			,,	,,	26726
3739·4		1			,,	,,	26735
3735·9		1			1·03	,,	26760
3732·2		1			,,	,,	26786
3731·6		1			,,	,,	26791
3728·9		1			,,	,,	26810
3728·3		1			,,	7·6	26814
3727·7		2n			,,	,,	26819
3725·6		1			,,	,,	26834
3722·9		2			,,	,,	26853
3722·6		1			,,	,,	26855
3716·8		1n			,,	,,	26897
3712·0		1n			,,	,,	26932
3706·8	3706·685	2	3	·667 ,,	,,	,,	26970·6
3705·3		1			,,	,,	26981
3700·4		1			,,	,,	27016
3700·3	3700·070	1	4	·059 ,,	,,	,,	27018·9
3699·2		1			,,	,,	27025
3695·0		1			1·02	,,	27056
3690·6		1			,,	,,	27088
3687·7	3687·582	8	4	·554 ,,	,,	,,	27110·5
3683·2	3683·169	1	4	·123 ,,	,,	7·7	27142·8
3682·5		1			,,	,,	27148

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}$ −	
3681·3	3681·227	1	0	·229 R.	1·02	7·7	27157·1
3680·8		1			,,	,,	27160
3680·2		1			,,	,,	27165
3676·1		1			,,	,,	27196
3675·2	3675·107	2	1		,,	,,	27202·4
3674·3	3674·207	6	4	·191 ,,	,,	,,	27209·0
3672·2	3672·165	6	4	·142 ,,	,,	,,	27224·2
3668 6	3668·564	1	1		,,	,,	27251·0
3666·5		1			,,	,,	27266
3664·5		1			,,	,,	27281
3663·5	3663·239	1	4	·242 ,,	,,	,,	27290·5
3662·0		1			,,	,,	27300
3659·6	3659·571	1	2	·564 ,,	,,	,,	27317·9
3658·3		1			,,	,,	27327
3654·9		1			1·01	,,	27353
3654·2	3654·132	1	1		,,	,,	27358·6
3653·5		1			,,	,,	27363
3652·5	3652·411	1	1		,,	,,	27371·5
3651·8		1			,,	,,	27376
3643·3	3643·331	6n	6	·313 ,,	,,	,,	27439·7
3639·0	3638·956	6	6	·944 ,,	,,	7·8	27472·6
3637·3		2			,,	,,	27485
3636·7		1			,,	,,	27490
3636·5		1			,,	,,	27491
3629 0	3629·025	6	3	·017 ,,	,,	,,	27547·8
3628·3	3628·275	8	5	·272 ,,	,,	,,	27553·5
3627·8		1			,,	,,	27557
3625·4		1			,,	,,	27575
3622·7		1n			,,	,,	27596
3621·8	3621·839	1	2	·812 ,,	,,	,,	27602·5
3617·3		1			1·00	,,	27637
3615·4	3615·443	1	0		,,	,,	27651·4
3611·0	3611·057	2	2	·060 ,,	,,	,,	27684·9
3608·0		1			,,	,,	27708
3606·8		1			,,	,,	27718
3605·4		1n			,,	,,	27728
3602·9		1			,,	,,	27748
3602·4		1n			,,	,,	27751
3594·4		1n			,,	7·9	27813
3589·2		1			,,	,,	27853
3587·7		1			,,	,,	27865
3587·1		1			,,	,,	27870
3585·8		1			,,	,,	27880
3585·4		1			,,	,,	27883
3583·2		1			,,	,,	27900
3578·8		1			,,	,,	27934
3578·0		1			0·99	,,	27941
3577·6		1			,,	,,	27944
3574·2		1			,,	,,	27970
3573·5		1			,,	,,	27976
3572·3		1			,,	,,	27985
3571·4		1			,,	,,	27992
3568·5		1			,,	,,	28015
3565·4		1n			,,	,,	28039
3559·9		1n			,,	,,	28083

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
3559·1		1			0·99	7·9	28089
3558·7		1			,,	,,	28092
3557·3		1			,,	,,	28103
3555·0		1			,,	,,	28122
3553·2		2			,,	,,	28136
3551·6		2			,,	8·0	28148
3550·3		1n			,,	,,	28159
3548·9		1			,,	,,	28170
3548·8		1			,,	,,	28171
3548·5		2			,,	,,	28173
3545·0		1			,,	,,	28201
3543·6		1			,,	,,	28212
3540·8		1			,,	,,	28234
3536·1		2			0·98	,,	28272
3534·3		1n			,,	,,	28286
3531·8		1			,,	,,	28306
3528·7	3528·700	1	2	·691 R.	,,	,,	28331·0
3526·9		1			,,	,,	28346
3526.3		1n			,,	,,	28350
3523·7		1n			,,	,,	28371
3522·6		1			,,	,,	28380
3519·7		1			,,	,,	28404
3518·6		1			,,	,,	28412
3514·9	3514·869	1	4	·887 ,,	,,	,,	28442·6
3513·7		2			,,	,,	28452
3505·9	3505·848	1	1	·835 ,,	,,	8·1	28515·7
3503·6		1			,,	,,	28534
3502·6		1			,,	,,	28542
3498·3	3498·321	1	1	·308 ,,	0·97	,,	28577·0
3498·0		1			,,	,,	28580
3492·0		1n			,,	,,	28629
3491·1	3491·155	1n	1	·141 ,,	,,	,,	28635·7
3490·2		2			,,	,,	28644
	3488·877		1		,,	,,	28654·4
3487·8		1			,,	,,	28663
3485·3	3485·430	6	6	·411 ,,	,,	,,	28682·8
3483·5	3483·588	4	5	·561 ,,	,,	,,	28697·9
3482·4		1			,,	,,	28707
3480·6		2			,,	,,	28723
3476·9		2			,,	,,	28753
3474·9		1			,,	,,	28770
	3472·080		0		,,	,,	28793·1
3471·4		1n			,,	,,	28799
3464·1	3464·097	1	2	·080 ,,	,,	8·2	28859·3
3460·9		1n			,,	,,	28886
3459·7		1			,,	,,	28896
3455·9		1			0·96	,,	28928
3454·2	3454·290	1	3	·285 ,,	,,	,,	28941·3
3453·9		2			,,	,,	28945
3449·0		1			,,	,,	28986
3448·5	3448·523	1	1n		,,	,,	28989 7
3447·9		2			,,	,,	28995
3441·5		1			,,	,,	29049
3434·9		4			,,	,,	29105
3431·9	3432·000	2	2	·032 ,,	,,	,,	29129·3

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda+$	$\frac{1}{\lambda}-$	
	3431·495		0		0·96	8·3	29133·5
3428·0	3428·079	4	4	·110 R.	"	"	29162·5
3426·9	3426·887	2	2	·880 "	"	"	29172·7
3425·7					"	"	29183
3424·8					"	"	29191
3422·1					"	"	29214
3421·2	3420·493	1	0		"	"	29227·3
	3418·311		0		"	"	29245·9
3417·1	3417·227	1	2		0·95	"	29255·2
3414·4	3414·610	1	2		"	"	29277·6
3409·3		1			"	"	29323
3408·6	3408·286	6	7	·277 "	"	"	29331·9
3407·7		1			"	"	29337
3406·7	3406·733	1	2		"	"	29345·4
3405·9		1			"	"	29353
3404·7		2			"	"	29363
3385·0		1			"	8·4	29534
3384·0		2			"	"	29542
3374·2		1n			0·94	"	29628
3373·2	3372·960	1	0		"	"	29639·2
3368·7	3368·626	1	2		"	"	29677·3
3367·2	3367·139	1n	4	·135 "	"	"	29690·4
3357·2		1			"	8·5	29778
3344·1	3344·031	2	4	·037 "	"	"	29895 5
3343·7		1			"	"	29899
3343·2		1			"	"	29903
3342·1	3342·429	1	1		"	"	29909·9
3341·3		1			"	"	29920
3340·4		1n			"	"	29928
3339·8		1			"	"	29933
3338·4		1n			0·93	"	29946
3338·1	3338·214	1	2		"	"	29947·7
3336·3		1n			"	"	29965
3334·1		1n			"	"	29985
3333·5		1			"	"	29990
3327·4	3327·234	1	0		"	"	30046·5
3326·1		1			"	"	30057
3325·9	3325·861	1	2		"	"	30058·9
3324·2		1			"	8·6	30074
3323·9	3323·914	2	6	·921 "	"	"	30076·5
3323·2		1			"	"	30083
3322·8		1			"	"	30087
3321·6		1			"	"	30097
3319·8		1			"	"	30114
3318·6		1			"	"	30125
3317·3		1n			"	"	30136
3315·6		1			"	"	30152
3315·2	3315·186	4	4	·182 "	"	"	30155 6
	3313·186		1		"	"	30173·8
3312·6	3312·614	2	3		"	"	30179·1
3312·1	3311·959	1	2		"	"	30185·0
3311·5	3311·504	1	1		"	"	30189·2
3310·2		1			"	"	30201
3308·0		1			"	"	30221
3307·8		1			"	"	30223

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda+$	$\frac{1}{\lambda}-$	
3305·9		1			0·93	8·6	30240
3304·3		1			,,	,,	30255
3303·0		1			,,	,,	30267
3301·9	3302·015	8	8n	·996 R.	,,	,,	30275·9
	3300·070		1n		,,	,,	30293·8
	3298·688		0n		0·92	,,	30306·5
3297·0		1			,,	,,	30322
3293·8	3293·820		0		,,	,,	30351·3
	3293·615		0		,,	,,	30353·1
3292·6		1			,,	,,	30363
3291·5		1			,,	,,	30373
3290·4	3290·363	4	6	·370 ,,	,,	,,	30383·2
3288·6		2n			,,	8·7	30399
3287·8		1n			,,	,,	30407
3286·8	3287·245	1	0		,,	,,	30411·9
3285·6	3285·367	2	0		,,	,,	30429·3
3284·9		1			,,	,,	30434
3284·6		1			,,	,,	30436
3283·4	3283·443	2	2	·436 ,,	,,	,,	30447·2
	3283·336		2	·332 ,,	,,	,,	30448·1
3282·6		1			,,	,,	30455
3282·0	3282·104	2	5	·097 ,,	,,	,,	30459·6
3279·9		1			,,	,,	30480
3278·6		1			,,	,,	30492
3277·5		1			,,	,,	30502
3274·0		6			,,	,,	30535
3273·1		1			,,	,,	30543
3272·1		1			,,	,,	30553
3270·8		1			,,	,,	30565
3269·3		1			,,	,,	30579
3268·5	3268·557	2	4	·570 ,,	,,	,,	30585·8
3267·1		1			,,	,,	30600
3266·5		1			,,	,,	30605
3266·2		1			,,	,,	30608
3265·5		1			,,	,,	30615
3264·2		1			,,	,,	30627
3263·9	3263·737	1	1		,,	,,	30631·0
3262·1		1			,,	,,	30646
3261·8	3261·818	2	4	·819 ,,	,,	,,	30649 0
3261·3	3261·202	1	2		,,	,,	30654·9
3259·8	3259·866	2	4	·859 ,,	0·91	,,	30667·4
3258·7	3259·282	1	1		,,	,,	30672·9
3258·3	3258·551	1	0		,,	,,	30679·8
3256·6	3256·634	1	1		,,	,,	30697·9
3256·0	3256·048	4	6	·038 ,,	,,	,,	30703·4
3255·3	3255·356	1	0		,,	,,	30709·9
8255·0		1			,,	,,	30713
8254·5		1			,,	,,	30718
	3253·319		0		,,	,,	30729·1
	3252·785		1		,,	8·8	30734·0
3252·0	3252·117	2	5	·103 ,,	,,	,,	30740·4
3250·4	3250·481	2	4	·475 ,,	,,	,,	30755·9
3249·1	3248·843	1	0		,,	,,	30771·4
	3248·623		2		,,	,,	30773·5
3247·6	3247·388	6	2		,,	,,	30785 2

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
3246·0		1			0·91	8·8	30798
3243·8	3243·533	2	2		,,	,,	30821·8
3242·9	3243·224	1	0		,,	,,	30824·8
3241·6	3241·652	1	1		,,	,,	20839·7
3240·9		1			,,	,,	30847
3240·3	3240·324	2	5	·323 R.	,,	,,	30852·4
3239·4		2			,,	,,	30861
3236·8		1			,,	,,	30886
3235·8		1n			,,	,,	30896
3233·58	3233·550	4	5	·541 ,,	,,	,,	30917·0
3230·42	3230·401	4	5	·406 ,,	,,	,,	30947·1
3229·4		1			,,	,,	30957
3227·3	3227·305	1	2	·290 ,,	,,	,,	30976·8
3225·5		1			,,	,,	30994
3224·1		1			,,	,,	31008
3223·7	3223·928	1	0		,,	,,	31009·2
	3222·930		0		,,	,,	31018·9
3222·6	3222·680	1	0		,,	,,	31021·3
	3221·416		0		,,	,,	31033·4
3220·9	3220·904	2	3		0·90	,,	31038·4
3219·7		1			,,	,,	31050
3218·9	3218·972	1n	9		,,	,,	31037·0
	3218·603		1		,,	,,	31060·6
3216·5		1n			,,	,,	31081
3213·5		1n			,,	8·9	31110
3212·4	3212·502	1	2	·493 ,,	,,	,,	31119·5
	3208·968		0		,,	,,	31153·8
	3207·347		0		,,	,,	31169·5
3204·27	3204·165	6	6	·161 ,,	,,	,,	31200·4
3203·1		1			,,	,,	31211
3202·6		1			,,	,,	31216
3201·9		1			,,	,,	31223
3201·0		4			,,	,,	31231
3200·79	3200·848	4	4	·830 ,,	,,	,,	31232·8
3199·1	3199·215	1n	0		,,	,,	31248·7
	3199·076		0		,,	,,	31250·1
3198·0		2			,,	,,	31261
3196·5		1			,,	,,	31275
3194·4		1			,,	,,	31296
3194·2		1			,,	,,	31298
3192·6	3192·635	1	3		,,	,,	31313·1
3191·3	3191·604	2	0		,,	,,	31323·3
3189·2		1			,,	,,	31347
3188·3		2			,,	,,	31356
3185·7		1			,,	,,	31381
3184·7		1			,,	,,	31391
3183·6		1n			,,	,,	31402
3181·5		1n			0·89	,,	31423
3179·1	3179·650	2	1		,,	9·0	31441·0
3177·8	3177·707	1	1		,,	,,	31460·2
3176·3	3176·081	1b	1n		,,	,,	31476·4
3175·0	3174·959	1	2		,,	,,	31487·5
3174·7		1			,,	,,	31490
3173·5		1			,,	,,	31502
3170·3		1b			,,	,,	31534

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ +	$\frac{1}{\lambda}$ −	
3169·1	3169·006	1	1		0·89	9·0	31546·6
3168·4		1			,,	,,	31553
3167·5		1n			,,	,,	31562
3164·6		1n			,,	,,	31591
3160·1	3160·314	1b	1		,,	,,	31633·5
3159·26	3159 841	4	0		,,	,,	31638·2
3156·70	3156·686	4	5	·683 R.	,,	,,	31669·8
3155·8		1			,,	,,	31679
	3154·858		1		,,	,,	31688·1
3149·5		1			,,	,,	31742
3148·6		1			,,	,,	31751
3146·3		1n			,,	9·1	31774
3145·2		2			,,	,,	31785
3144·3		2			,,	,,	31795
3142·0	3141·767	2	4		,,	,,	31820·1
3139·51	3139·503	4	7	·505 ,,	0·88	,,	31843·1
3137·8		1			,,	,,	31860
3137·3		1			,,	,,	31865
	3136·381		0		,,	,,	31874·8
3135·1		1			,,	,,	31888
	3134·413		1		,,	,,	31894·8
	3133·785		1		,,	,,	31901·1
3133·5	3133·443	2	4		,,	,,	31904·7
	3132·187		0		,,	,,	31917·4
3127·1		2			,,	,,	31969
3126·3		1n			,,	,,	31978
3124·1		1n			,,	,,	32000
3122·8	3123·065	1n	0		,,	,,	32010·7
3122·1	3122·192	1n	0		,,	,,	32019·7
3121·3		1			,,	,,	32029
3121·0		1			,,	,,	32032
3119·9	3119·911	2	4		,,	,,	32043·1
3119·0		1			,,	,,	32053
	3118·547		0		,,	,,	32057·1
3118·1		1n			,,	,,	32062
3117·4		1n			,,	,,	32069
3117·0		2			,,	,,	32073
3115·6		1b			,,	,,	32088
3114·5		1b			,,	9·2	32099
3113·0	3112·718	1b	0		,,	,,	32117·1
3111·8		1b			,,	,,	32127
3109·5		1			,,	,,	32150
3108 7		1			,,	,,	32159
3108·2		1			,,	,,	32164
3104·8	3104·170	1	0		,,	,,	32205·5
3104·0	3103·704	2	2		,,	,,	32210·4
	3103·231		1		,,	,,	32215·3
3102·4	3102·710	1	0		,,	,,	32220·7
3101·1	3101·077	2	4	·070 ,,	0·87	,,	32237·6
3100·1	3100·146	4	4	·136 ,,	,,	,,	32247·3
3098·0	3098·887	1	0n		,,	,,	32260·4
3097·1		1			,,	,,	32279
3089·3	3089·780	1	0		,,	,,	32355·6
3088·1	3088 677	1	0		,,	,,	32367·1

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}$−	
	3087·319		0		0·87	9·2	32381·4
3084 9	3084·978	1	2		,,	,,	32405·9
3084·1	3084·217	2	3		,,	,,	32413·9
3082·5	3082·779	1	0		,,	9·3	32429·0
3081·1	3081·172	1	0		,,	,,	32445·9
3079·8	3079·674	1n	4		,,	,,	32461·7
	3078·948		0		,,	,,	32469·3
3076·8		2			,,	,,	32492
3076·1		1			,,	,,	32499
	3075·122		0		,,	,,	32509·8
3074·3	3074·938	1	1		,,	,,	32511·7
3072·1	3072·042	2	5	·042 R.	,,	,,	32542·3
3070·3	3070·369	1	2		,,	,,	32560·1
3069·8	3069·207	1	2		,,	,,	32572·4
3067·9		1			,,	,,	32586
3064·6	3064·825	8	6r	·824 ,,	,,	,,	32618·9
3063·6		1			,,	,,	32632
	3062·845		0		0·86	,,	32640·0
	3062·3		0n		,,	,,	32645·9
	3061·905		1		,,	,,	32650·1
3059·8	3059·748	2	4	·749 ,,	,,	,,	32673·1
3059·2		1n			,,	,,	32679
3058·5		1n			,,	,,	32687
3057·5		1n			,,	,,	32697
3056·1	3056·719	2	0		,,	,,	32705·5
3055·5	3055·402	2	4		,,	,,	32719·6
3054·9	3054·8	1	2n		,,	,,	32726·1
	3054·4		2n		,,	,,	32730·4
3049·6		1			,,	9·4	32782
3049·2		1			,,	,,	32786
3048·1	3048·6	1	2n		,,	,,	32792·5
3047·3		2			,,	,,	32807
3045·8		1			,,	,,	32823
3044·9		1			,,	,,	32832
3042·8	3042·752	4 Ir?	4r	·745 ,,	,,	,,	32855·6
3041·3	3041·323	2	2		,,	,,	32871·1
3040·8		1			,,	,,	32877
	3039·612		0		,,	,,	32889·6
3036·6	3036·554	4	6	·563 ,,	,,	,,	32922·7
3034·5		1			,,	,,	32945
3033·6		1			,,	,,	32955
3031·20		4			,,	,,	32980·8
3029·6		1			,,	,,	32998
3028·2		1			,,	,,	33014
3026·5	3026·446	1	2		,,	,,	33032·6
3025·3	3025·671	2	2		,,	,,	33041·1
	3025·179		2		,,	9·5	33046·4
3024·5	3024·410	1	2		,,	,,	33054·8
3022·9	3022·957	1	3		0·85	,,	33070·7
3021·1		1			,,	,,	33091
3020·7		1			,,	,,	33095
	3019·961		0		,,	,,	33103·5
3019·0		2			,,	,,	33114
3017·95	3018·003	4	4	·983 ,,	,,	,,	33125·0
3017·35	3017·450	4	2		,,	,,	33131·1

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
	3015·510		2		0·85	9·5	33152·4
3015·2	3015·013	2n	0		,,	,,	33157·9
	3014·636		0		,,	,,	33162·0
3012·6	3012·498	2	2		,,	,,	33185·5
*3011·6		1n			,,	,,	33195
3010·9		1			,,	,,	33203
	3010·051		0		,,	,,	33212·5
3008·1		1n			,,	,,	33234
3007·7		1			,,	,,	33239
3006·0	3005·911	1n	2		,,	,,	33258·3
3004·4	3004·269	1n	2		,,	,,	33276·5
3003·6	3003·400	1	2		,,	,,	33286·1
3003·3		1			,,	,,	33287
3002·28	3002·385	4	4	·388 R.	,,	,,	33297·3
3001·23	3001·304	6	2		,,	,,	33309·4
3000·2		1			,,	,,	33322
2999·2		2			,,	,,	33333
2998·07	2998·087	2	7r	·079 ,,	,,	,,	33345·1
2996·0		1			,,	9·6	33368
	2994·916		2		,,	,,	33380·3
2993·3		1			,,	,,	33398
2991·8		1			,,	,,	33415
2990·0	2989·915	1	4		,,	,,	33436·1
	2988·913		0		,,	,,	33447·4
	2988·177		0		,,	,,	33455·6
2987·1		1			,,	,,	33468
2985·6		1			,,	,,	33485
2985·1		1			,,	,,	33490
	2984·565		0		,,	,,	33496·1
2984·0	2983·882	1	2		,,	,,	33503·8
2983·1		1			,,	,,	33513
	2982·414		0		0·84	,,	33520·3
2980·1		2			,,	,,	33546
2979·4		2			,,	,,	33554
2978·3	2978·179	1	2		,,	,,	33568·0
2975·9		1n			,,	,,	33594
2975·1		1			,,	,,	33603
2973·9	2974·252	2	0		,,	,,	33612·3
2973·4		1n			,,	,,	33622
2971·8		1n			,,	,,	33640
	2969·965		0		,,	9·7	33660·7
2968·9		1			,,	,,	33673
2967·1	2967·596	1	0		,,	,,	33687·6
2964·8		1			,,	,,	33719
2964·6		1			,,	,,	33722
2962·9		1			,,	,,	33741
2962·3		1			,,	,,	33748
2961·3		1			,,	,,	33759
2960·8	2960·864		5n		,,	,,	33764·3
	2959·825		1		,,	,,	33776·0
2959·2	2959·219	2	4		,,	,,	33783·0
2958·6	2958·650	2	0		,,	,,	33789·5
2957·6		1n			,,	,,	33802
2955·9		2			,,	,,	33821
2955·0		1n			,,	,,	33831

* Double.

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
2954·6		1n			0·84	9·7	33836
2954·1		1n			"	"	33842
2951·3	2951·341	1	2		"	"	33873·2
2950·3	2950·929	1	0		"	"	33877·9
2949·3	2949·900	1	2		"	"	33889·8
	2948·844		0		"	"	33901·9
2947·6		1n			"	"	33916
2947·0		1n			"	"	33923
2946·3		1			"	"	33931
2944·8	2944·879	2	3		"	9·8	33947·4
2943·2		1			"	"	33967
2942·8	2942·880		4		0·83	"	33970·5
	2941·908		0		"	"	33981·7
	2941·219		2		"	"	33989·7
2939·4		1			"	"	34011
2938·9	2938·935	2	4		"	"	34016·1
2938·2		1n			"	"	34025
2937·3		1			"	"	34035
2936·7		1			"	"	34042
2934·7		1			"	"	34065
2933·3	2933·837	1	0		"	"	34075·2
2931·7		2			"	"	34100
2930·9	2930·904	2	4		"	"	34109·4
2929·89	2929·903	6	8r		"	"	34121·1
2928·7		1			"	"	34135
2928·3	2928·226	1	4		"	"	34140·5
	2927·040		1		"	"	34154·4
2925·2		1			"	"	34176
2924 9		2			"	"	34179
	2922·381		0		"	"	34208·9
2921·5	2921·498		3		"	"	34219·2
	2921·336		1		"	9·9	34221·0
2919·43	2919·451		4		"	"	34243·1
2918·2		1			"	"	34258
2917·7		1			"	"	34264
	2916·505		2		"	"	34277·7
	2915·278		0		"	"	34292·1
2914·2	2914·443	2	0		"	"	34302·0
2913·65	2913·655	4	4		"	"	34311·2
	2913·361		2		"	"	34314·7
2912·35	2912·884	4	0		"	"	34320·4
	2911·888		0		"	"	34332·1
2910·6	2910·569	1	3		"	"	34347·6
2910·2		1			"	"	34352
	2908·928		0		"	"	34367·0
2908·1	2908·008	1	4		"	"	34377·9
2905·9	2906·001	2	4		"	"	34401·7
	2904·258		0		"	"	34422·3
	2903·129		0		0·82	"	34435·7
	2901·798		0		"	"	34451·5
	2901·282		2		"	"	34457·6
	2900·903		0		"	"	34462·2
2899·80	2899·764	4	1		"	"	34475·7
2898·03	2897·988	4	5		"	"	34496·8
2897·2		1			"	"	34506

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
	2896·245		1		0·82	10·0	34517·4
2895·7		1			"	"	34524
2894·02	2893·984	4	6		"	"	34544·5
2893·4	2893·335	2	4		"	"	34552·1
	2891·873		0		"	"	34569·7
	2891·170		0		"	"	34578·1
	2891·030		2		"	"	34579·8
2890·54	2890·495	4	2		"	"	34586·1
2889·8		1			"	"	34595
2888·2	2888·307	2	4		"	"	34612·3
2885·5	2885·447	2	0		"	"	34646·6
	2884·583		1		"	"	34657·1
2883·0		1			"	"	34676
2882·7		1			"	"	34680
2880·9		1			"	"	34701
	2878·823		1n		"	"	34726·5
2877·61		6n			"	"	34741·1
2875·9		4			"	"	34762
2875·22		4n			"	"	34769·9
2871·8		1n			"	10·1	34811
2870·4	2870·572	1	4		"	"	34826·2
2870·2		1			"	"	34831
	2868·783		0		"	"	34848·0
2867·06		4			"	"	34868·8
2866·1		2			"	"	34881
2865·22		4n			"	"	34891·2
2863·0		1			0·81	"	34918
2862·1		1			"	"	34929
2860·80		4n			"	"	34945·2
2859·5		1			"	"	34961
*2858·5		2n			"	"	34973
	2855·866		0		"	"	35005·5
2854·7	2854·781		0		"	"	35018·9
	2853·484		2		"	"	35034·8
2853·1	2853·207	2	4		"	"	35038·1
2852·3		1n			"	"	35049
2851·0		1n			"	"	35065
2849·8	2849·241		1		"	"	35087·0
2848·0	2848·406	1	0		"	10·2	35097·1
2845·5		1			"	"	35133
2844·4		1			"	"	35147
2842·1		2			"	"	35175
2840·0		1			"	"	35201
2839·1	2839·345	1	2		"	"	35209·1
2838·5		1			"	"	35220
2838·1	2837·643	1	0		"	"	35230·4
2837·3	2837·338	1	2		"	"	35234·1
2836·5		1			"	"	35245
2834·8	2834·815	1	0		"	"	35265·4
2831·6	2831·981	1	0		"	"	35300·8
2830·43	2830·402	4	8r		"	"	35320·5
2828·9		1			"	"	35339
2827·8		1			"	"	35353
2826·5		1			"	"	35369
2824·6	2825·192	1	1		"	"	35385·6

* Double.

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
2823·3	2822·602	2	2		0·80	10·3	35409
2822·5		1n			,,	,,	35418·0
	2822·273		0		,,	,,	35422·1
	2821·179		0		,,	,,	35435·9
2819·0		1			,,	,,	35463
2818·6	2818·741	1	2		,,	,,	35466·5
2818·4	2818·354	1	4		,,	,,	35471·5
2817·3		2n			,,	,,	35485
2816·1		1			,,	,,	35500
2815·5		1			,,	,,	35507
2814·1	2814·121	2	0		,,	,,	35524·8
2813·5	2813·080	1	2		,,	,,	35537·9
	2810·921		0		,,	,,	35565·2
2809·7		2			,,	,,	35581
2808·9		2			,,	,,	35591
2808·7	2808·603	1	4		,,	,,	35594·6
2807·1	2807·396	1	0		,,	,,	35609·8
	2806·151		0		,,	,,	35625·7
2805·3		1n			,,	,,	35637
2803·5	2803·338	1	6		,,	,,	35661·4
2802·8		1			,,	,,	35668
2801·8		1			,,	,,	35681
2800·1	2800·560	1n	0		,,	,,	35696·3
2799·7		1			,,	,,	35708
2798·1		1n			,,	10·4	35728
2797·8		2			,,	,,	35732
2795·5	2796·165	2	1		,,	,,	35752·8
2794·32	2794·304	6	5r		,,	,,	35776·7
2793·7	2793·736	2	2		,,	,,	35783·9
2793·3	2793·372	2	4		,,	,,	35788·7
2791·8		1n			,,	,,	35809
	2790·987		0		,,	,,	35819·2
	2790·593		0		,,	,,	35824·3
2789·8		1			,,	,,	35835
2789·5		1			,,	,,	35838
2788·6	2788·728	2	0		,,	,,	35848·2
2784·7		1			,,	,,	35900
2783·6		1			0·79	,,	35914
2782·7		1			,,	,,	35926
2779·2		1			,,	,,	35971
	2777·558		0		,,	,,	35992·4
2777·0	2776·859	1	0		,,	,,	36001·5
	2776·111		1		,,	,,	36011·2
2774·88	2774·880	6	2		,,	10·5	36027·1
	2774·306		3		,,	,,	36034·5
2774·0	2774·095	1	4		,,	,,	36037·2
2773·6	2773·696	2	2		,,	,,	36042·4
	2772·925		4		,,	,,	36052·4
2771·78	2771·750	4	4r		,,	,,	36067·8
2769·8	2769·940	1	4		,,	,,	36091·4
2769·0		1			,,	,,	36101
2767·4		1			,,	,,	36125
2766·6	2766·764	1	5		,,	,,	36132·9
2764·2		1n			,,	,,	36166
2763·30	2763·299	4	0		,,	,,	36178·1

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda+$	$\frac{1}{\lambda}-$	
2761·5		1			0·79	10·5	36202
2759·8	2759·424	1	0		,,	,,	36229·0
2758·7	2758·333	1	2		,,	,,	36243·3
	2758·164		0		,,	,,	36245·6
2757·5	2757·799	2n	2		,,	,,	36250·3
2755·7		1			,,	,,	36278
2755·03	2755·003	4	4		,,	,,	36287·1
	2754·327		0		,,	,,	36296·0
	2753·957		3		,,	,,	36300·8
2753·8	2753·850	2	2		,,	,,	36302·3
2753·3		1			,,	,,	36310
2753·1		1			,,	,,	36312
2752·6		1			,,	,,	36319
2752·0		1			,,	,,	36327
2751·4		1			,,	,,	36335
2750·0		1			,,	10·6	36353
2749·3		2			,,	,,	36362
2747·7	2747·701	2	4		,,	,,	36383·5
2747·0		1			,,	,,	36393
2746·6		1			,,	,,	36398
2745·4		1			,,	,,	36414
2745·0	2744·928	1	2		,,	,,	36420·2
2743·5		1b			,,	,,	36439
2742·4		1			,,	,,	36454
2741·5		1n			0·78	,,	36466
2740·5		1n			,,	,,	36479
2739·6		1			,,	,,	36491
2738·5	2738·569	2	4		,,	,,	36505·8
2737·6	2737·656	1	2		,,	,,	36516·9
	2736·886		0		,,	,,	36527·2
2735·8		2			,,	,,	36542
2734·5	2734·584	1	2		,,	,,	36558·1
2734·08	2734·057	4n	8r		,,	,,	36565·0
	2733·725		5r		,,	,,	36569·5
2732·1		1n			,,	,,	36591
2729·9	2730·002	1	5		,,	,,	36619·4
2727·5		1			,,	,,	36653
2726·55		4			,,	10·7	36666
	2725·433		2		,,	,,	36680·8
2721·8		1			,,	,,	36730
2721·1		1			,,	,,	36739
2719·7		2			,,	,,	36758
2719·20	2719·125	4	6r		,,	,,	36765·8
2717·75	2717·709	4	0		,,	,,	36785·0
2715·8	2715·866	1	2		,,	,,	36809·9
	2714·613		0		,,	,,	36827·0
2713·1	2713·215	2	4		,,	,,	36845·9
2711·0		2			,,	,,	36876
2708·0		1			,,	,,	36917
2707·3		1			,,	,,	36927
2706·05	2705·985	4	5r		,,	,,	36944·4
2704·5		1			,,	,,	36965
2704·1		1			,,	,,	36970
2702·50	2702·484	6	6r		,,	10·8	36992·2
2701·2	2701·208	1	0		,,	,,	37009·6

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}$ –	
2699·5		1			0·78	10·8	37033
2698·55	2698·498	4	6		0·77	"	37046·8
2697·3		1n			"	"	37063
	2696·069		0		"	"	37080·2
2694·3	2694·314	1	4		"	"	37104·5
2694·1		1			"	"	37107
2692·3		2			"	"	37132
2689·5		2			"	"	37171
	2688·352		2		"	"	37186·7
	2686·990		0		"	"	37205·6
2681·9		1			"	"	37276
2680·2		1			"	"	37300
2679·3		2			"	"	37312
2677·3	2677·232	2	5r		"	10·9	37341·1
2677·0		1			"	"	37344
2676·2		1			"	"	37356
2674·8	2674·649	2	4		"	"	37377·2
	2673·707		0		"	"	37390·3
2672·8		1			"	"	37403
2668·8	2668·748	1n	0		"	"	37459·8
2666·8		1			"	"	37487
2664·8	2664·723	1	2		"	"	37516·5
2662·0		1			"	"	37555
2661·6		1			"	"	37561
2659·60	2659·535	6	10r		"	"	37589·6
2658·8	2658·790	1	2		"	"	37600·2
2658·2	2658·266	1	4		"	"	37607·5
2657·8		1			"	"	37614
	2656·907		0		"	"	37626·8
	2653·867		0		0·76	11·0	37669·8
2651·5		1			"	"	37704
2651·00	2650·938	4	4r		"	"	37711·5
2647·00	2646·969	4	6r		"	"	37768·0
2645·4	2645·453	1	4		"	"	37789·7
2639·8	2639·434	1	5		"	"	37876·0
2639·3		2			"	"	37878
2635·7	2635·372	1	0		"	"	37934·3
2634·9		2			"	"	37941
2631·2		1			"	11·1	37994
2628·13	2628·122	6	7r		"	"	38038·9
2627·5	2627·484	1	4		"	"	38048·2
2625·41	2625·419	6	2		"	"	38078·0
2623·1		1n			"	"	38112
2621·5		1			"	"	38135
2620·9		1			"	"	38144
2619·6	2619·977	2n	0		"	"	38157·1
	2619·668		4		"	"	38161·6
2616·75	2616·839	4	0		"	"	38202·5
	2614·701		2		"	"	38234·2
2613·8	2613·337	1n	0		"	"	38254·1
	2613·204		0		"	"	38256·2
2612·7		1			"	"	38264
2611·8		1			"	"	38277
2611·2		1			0·75	"	38286
2608·8		1			"	11·2	38321

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Keyser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
2608·0	2608·333	1n	0		0·75	11·2	38327·5
2607·0		1n			,,	,,	38347
	2606·126		0		,,	,,	38359·9
2603·5		1			,,	,,	38399
2603·2	2603·223	1	4		,,	,,	38402·8
	2602·182		0		,,	,,	38418·1
2600·2	2599·986	1n	2		,,	,,	38450·5
2599·4	2599·148	1	0		,,	,,	38462·9
2598·2		1			,,	,,	38477
2595·8	2596·081	2	4		,,	,,	38508·4
2595·3		1			,,	,,	38520
2590·8		1			,,	,,	38587
	2587·890		2		,,	11·3	38630·2
2585·8		1			,,	,,	38662
2582·9	2582·415	1	2		,,	,,	38712·1
2579·4		1			,,	,,	38757
2578·9		1			,,	,,	38765
2578·1		2			,,	,,	38777
2577·0		1n			,,	,,	38794
2574·7	2574·580	1	2		,,	,,	38829·8
2574·2		1			,,	,,	38836
2572·70	2572·723	4	0		,,	,,	38858·1
2568·4		2			,,	11·4	38923
2566·1		1			,,	,,	38958
2564·0	2564·263	1	0		0·74	,,	38986·2
2562·5		1			,,	,,	39013
2560·4	2560·438	1	0		,,	,,	39044·4
2556·9		1			,,	,,	39099
2555·6		1			,,	,,	39118
2554·8		1			,,	,,	39131
2552·6		1			,,	,,	39164
2552·2	2552·326	1	3		,,	,,	39168·5
2549·4	2549·552	1n	3		,,	,,	39211·2
	2548·194		0		,,	11·5	39232·0
	2546·986		0		,,	,,	39250·5
	2546·562		0		,,	,,	39257·2
	2544·807		2		,,	,,	39284·2
2544·0	2544·042	1	4		,,	,,	39296·1
2542·8		1			,,	,,	39315
2541·3	2541·433	1	2		,,	,,	39336·4
2539·1	2539·285	1n	3		,,	,,	39369·6
	2538·361		0		,,	,,	39384·0
2536·4	2536·581	1n	4		,,	,,	39411·7
	2536·063		2		,,	,,	39419·6
2534·5		1			,,	,,	39444
2533·0		1			,,	,,	39467
2531·9		1			,,	,,	39485
	2529·499		2		,,	11·6	39521·9
2526·0		1			,,	,,	39577
2524·4		1n			,,	,,	39602
2523·6		1			,,	,,	39614
	2522·616		0		,,	,,	39631·3
2520·6	2520·356	1	0		,,	,,	39665·3
2519·0		1			,,	,,	39687
	2517·273		1		0·73	,,	39714·0

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Kayser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
2515·6	2515·666	2	3		0·73	11·6	39739·2
2515·1	2515·119	1	3		,,	,,	39747·9
	2514·165		2		,,	,,	39763·0
2513·98	2513·999	6	0		,,	,,	39765·7
2512·6		1			,,	,,	39788
2512·0		1			,,	,,	39797
	2510·604		0		,,	11·7	39819·4
2508·5	2508·589	1	3		,,	,,	39851·3
2505·9	2506·014	1n	4		,,	,,	39892·4
	2504·128		2		,,	,,	39922·3
	2503·075		2		,,	,,	39939·1
	2500·895		0		,,	,,	39973·9
2498·6	2498·592	2	4		,,	,,	40010·9
2498·0		1			,,	,,	40020
2497·3	2497·197	1n	1		,,	,,	40033·2
2495·95	2495·910	4	4		,,	,,	40053·8
2493·1		1			,,	11·8	40099
2492·6		1			,,	,,	40107
2491·5		1			,,	,,	40125
2490·1	2490·217	2	2		,,	,,	40145·3
2489·7		1			,,	,,	40154
2489·00	2488·819	4	4		,,	,,	40167·9
2487·15	2487·216	6	4r		,,	,,	40193·7
2483·4	2483·452	1	2		,,	,,	40254·8
2482·10	2483·312	4	2		,,	,,	40256·9
2481·3	2481·270	1n	2		,,	,,	40290·1
2480·6		1			,,	,,	40301
2480·2		1			,,	,,	40308
2479·1		1			,,	,,	40325
	2477·365		0		,,	,,	40353·6
2476·0		1			,,	11·9	40376
2475·3		1			,,	,,	40387
	2473·247		0		,,	,,	40420·7
2472·0		1n			,,	,,	40441
2470·9	2471·092	1n	3		,,	,,	40456·1
2469·4	2469·537	1n	0		0·72	,,	40481·5
2467·70	2467·504	6	6r		,,	,,	40514·9
2462·5		1n			,,	,,	40597
2461·1	2461·474	1	0		,,	,,	40614·2
	2460·160		1		,,	,,	40635·9
2458·9		1n			,,	12·0	40657
2455·2		1			,,	,,	40718
2451·0	2451·046	1	3		,,	,,	40786·8
2450·58	2450·527	4	2		,,	,,	40795·5
2445·5		1			,,	,,	40879
2444·5		1n			,,	,,	40896
2443·2		1			,,	12·1	40918
2442·75		4			,,	,,	40925·4
2440·1	2440·158	2	4r		,,	,,	40968·8
	2439·533		1		,,	,,	40979·4
2436·7	2436·771	1	4r		,,	,,	41025·8
2434·62	2434·551	4	0		,,	,,	41063·3
2433·6		1			,,	,,	41079
2432·9		1			,,	,,	41091

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Keyser Arc	Spark	Arc		$\lambda +$	$\frac{1}{\lambda} -$	
2432·0		1			0·72	12·1	41106
2429·4	2429·186	1n	2		,,	,,	41153·9
2428·2	2428·206	1n	8r		,,	12·2	41170·4
2426·7	2426·523	1	2		,,	,,	41199·1
2425·03	2424·964	6	2		,,	,,	41225·6
2423·3		1			,,	,,	41254
2422·6		1n			,,	,,	41266
2421·00	2420·912	4	0		0·71	,,	41294·6
2418·1	2418·151	2	3		,,	,,	41341·7
2417·9		1			,,	,,	41346
2415·0		1			,,	,,	41396
2413·3	2413·138	1n	1		,,	,,	41427·6
2412·1		1n			,,	12·3	41445
2410·4		1n			,,	,,	41475
2406·7		1			,,	,,	41538
2405·7		1n			,,	,,	41556
2405·0		1			,,	,,	41568
	2403·180		4r		,,	,,	41599·2
2403·1		1n			,,	,,	41601
	2401·959		3		,,	,,	41620·4
2401·1	2401·089	1	1		,,	,,	41635·4
2400·4		1			,,	,,	41647
2396·72	2396·762	4	0		,,	12·4	41710·6
2396·2	2396·243	1	2		,,	,,	41719·7
2395·6		1			,,	,,	41731
	2391·856		0		,,	,,	41796·1
2390·8		1			,,	,,	41815
2389.7	2389·615	1	3		,,	,,	41835·3
2387·4	2387·448	1	0		,,	,,	41873·3
2386·6	2386·886	1n	0		,,	,,	41883·1
2384·4		1n			,,	,,	41927
2383·7	2383·732	1	4		,,	,,	41938·7
2382·0		1			,,	12·5	41969
2381·4		1			,,	,,	41980
	2380·035		0		,,	,,	42003·6
2379·0		1			,,	,,	42022
2377·28		6			,,	,,	42052·4
2375·7		1			,,	,,	42080
2375·1		1			,,	,,	42091
2374·8		1			,,	,,	42096
2373·4		1			0·70	,,	42121
2373·0		1			,,	,,	42128
2371·7		1			,,	,,	42151
2369·9		1			,,	,,	42183
2368·4	2368·357	1	4r		,,	12·6	42210·7
2368·1		1			,,	,,	42215
2366·6		1			,,	,,	42242
2365·5		1			,,	,,	42262
2364·8		1			,,	,,	42274
2364·0		1			,,	,,	42289
2357·7	2357·656	1	0		,,	,,	42402·3
2357·2	2357·181	1n	4r		,,	,,	42411·0
2356·4	2356·415	1	0		,,	,,	42424·7
	2353·123		0		,,	12·7	42484·1

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Keyser Arc	Spark	Arc		$\lambda+$	$\frac{1}{\lambda}-$	
2351·5		1			0·70	12·7	42513
2348·6		1			,,	,,	42566
	2347·239		0		,,	,,	42590·5
	2346·822		0		,,	,,	42598·2
2343·4	2343·468	1	0		,,	,,	42659·1
2342·8		1			,,	,,	42671
2340·2	2340·255	1	2		,,	12·8	42717·5
2339·5		1			,,	,,	42731
2339·1		1			,,	,,	42739
2335·2		1			,,	,,	42810
2326·4	2326·185	1n	2		,,	12·9	42975·9
2323·2		1			0 69	,,	43031
2320·1		1n			,,	,,	43089
2318·3	2318·371	1	2		,,	,,	43020·9
2315·4	2315·58	1n	2		,,	,,	43072·8
2314·2		1			,,	13·0	43199
2313·7		1			,,	,,	43208
2312·9		1n			,,	,,	43223
2310·9		2			,,	,,	43260
2308·1	2308·12	1n	3		,,	,,	43312·3
2307·8		1			,,	,,	43318
2306·3		1			,,	,,	43347
2305·8	2305·72	1	2		,,	,,	43357·4
2304·6		1			,,	,,	43379
2304·3		1			,,	,,	43384
2302·5		1			,,	,,	43418
2297·5		1			,,	13·1	43513
2296·1		2			,,	,,	43539
2293·7		1			,,	,,	43585
2292·8		1			,,	,,	43602
2292·0		1			,,	,,	43617
2291·7		1			,,	,,	43623
2289·6		1			,,	,,	43663
2288·4		4n			,,	13·2	43686
2287·7		2			,,	,,	43699
2286·8		1			,,	,,	43716
2285·9		1			,,	,,	43733
2285·3		1			,,	,,	43745
2281·6		1			,,	,,	43816
2280·9		1			,,	,,	43829
2276·4		1			0·68	,,	43917
2274·6		1n			,,	13·3	43951
2271·9		1			,,	,,	44003
2270·1		1n			,,	,,	44038
2269·1		1			,,	,,	44057
2268·5		1			,,	,,	44069
2267·5		1			,,	,,	44088
2266·7		1n			,,	,,	44104
2264·3		1n			,,	,,	44151
2263·6		1			,,	,,	44164
2263·0		1			,,	13·4	44176
2259·8		1			,,	,,	44238
2259·0		1			,,	,,	44254
2256·4		1n			,,	,,	44305

PLATINUM (SPARK AND ARC SPECTRA)—*continued.*

Wave-length		Intensity and Character		Previous Observations (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Exner and Haschek Spark	Keyser Arc	Spark	Arc		λ+	$\frac{1}{\lambda}-$	
2254·8		1			0·68	13·4	44336
2253·3		1			,,	,,	44366
2251·6		2			,,	,,	44400
2250·7		1			,,	13·5	44417
2247·4		1n			,,	,,	44482
2245·6		1n			,,	,,	44518
2242·7		1n			0·67	,,	44576
2235·4		1n			,,	13·6	44721
2229·1		1			,,	,,	44848
2218·4		1n			,,	13·7	45064
2210·4		1n			,,	13·8	45227
2210·0		1			,,	,,	45235
2205·1		1			,,	,,	45336
2204·0		1			,,	,,	45358
2202·0		1			,,	13·9	45399
2192 4		1n			0·66	14·0	45598
2190·4		1n			,,	,,	45640
2177·0		1			,,	14·1	45921
2150·4		1			,,	14·3	46489
2149·8		1			,,	,,	46502
2148·9		1			,,	,,	46521
2144·4		1n			0·65	14·4	46619
2130·7		1			,,	14·5	46918

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Professor W. R. DUNSTAN, Mr. GEORGE GLADSTONE, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Sir H. E. ROSCOE, *and* Professor S. P. THOMPSON.

YOUR Committee are able to report that the quantity, if not the quality, of the teaching of Science subjects in Elementary Schools has made progress during the past year. The following table, made up from the return issued by the Education Department, gives the figures for the scientific class subjects as compared with English. In the report for last year it was mentioned that the number of school departments taking object lessons would greatly increase, as the Government code of regulations announced that they would become obligatory in the three lower standards on and after September 1, 1896. We now see the result, so far as the schools are concerned whose school year ended between August 31, 1896, and August 31, 1897, but the full effect cannot appear until the next year's return, the whole of which will be within the obligatory period.

Class Subjects—Departments	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97
English . . .	19,825	18,175	17,394	17,032	16,280	15,327	14,286
Geography . . .	12,806	13,485	14,256	15,250	15,702	16,171	16,646
Elementary Science .	173	788	1,073	1,215	1,712	2,237	2,617
Object Lessons . .	—	—	—	—	—	1,079	8,321

The number of departments in 'schools for older scholars' for the year 1896–97 was 23,080, all but 10 of which took one or more class subjects. But History was taken in 5,133 departments, and needlework (as a class subject for girls) in 7,397 departments, and sundry minor subjects in 1,056, making, with the other four subjects of the table, a total of 55,456. This shows an average of more than 2⅓ class subjects to each department; but it must be borne in mind that the same subject is not always taken in all the standards, in which case three class subjects will appear in the return.

It was remarked in the last report that 'the increased teaching of scientific specific subjects in the higher standards is the natural consequence of the greater attention paid to natural science in the lower part of the schools.' The following table shows the correctness of this inference:—

Specific Subjects.—Children	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97
Algebra	28,542	31,487	33,612	38,237	41,846	47,225
Euclid	927	1,279	1,399	1,468	1,584	2,059
Mensuration . . .	2,802	3,762	4,018	5,614	6,859	8,619
Mechanics . . .	18,000	20,023	21,532	23,806	24,956	26,110
Animal Physiology . .	13,622	14,060	15,271	17,003	18,284	19,989
Botany	1,845	1,968	2,052	2,483	2,996	3,377
Principles of Agriculture.	1,085	909	1,231	1,196	1,059	825
Chemistry . . .	1,935	2,387	3,043	3,850	4,822	5,545
Sound, Light, and Heat .	1,163	1,168	1,175	914	937	1,040
Magnetism and Electricity	2,338	2,181	3,040	3,198	3,168	3,431
Domestic Economy . .	26,447	29,210	32,922	36,239	39,794	45,869
Total . . .	98,706	108,434	119,295	134,008	146,305	164,089

It appears that the mathematical subjects still command the most favour on the part of the teachers, Algebra having taken a very remarkable lead. All the physical sciences have increased even more than might have been expected from the increase of scholars. The Principles of Agriculture is the only subject that shows an actual decrease.

Estimating the number of scholars in Standards V., VI., and VII. at 615,000, the percentage of the number examined in these specific subjects, as compared with the number of children qualified to take them, is 26·6; but it should be remembered that many of the children take more than one subject for examination. The following table gives the percentage for each year since 1882, and shows that Science is gradually recovering from the great depression of about eight years ago :—

1882–83	29·0 per cent.	1890–91	20·2 per cent.
1883–84	26·0 „	1891–92	19·7 „
1884–85	22·6 „	1892–93	20·2 „
1885–86	19·9 „	1893–94	20·9 „
1886–87	18·1 „	1894–95	22·7 „
1887–88	16·9 „	1895–96	24·2 „
1888–89	17·0 „	1896–97	26·6 „
1889–90	18·4 „		

The Returns of the Education Department here given refer to the whole of England and Wales, and are for the school years ending with August 31. The statistics of the London School Board are brought up to the year ending with Lady Day, 1898. They also illustrate the great advance that has been made in the teaching of Elementary Science as a class subject, and they give the number of children as well as the number of departments.

Years	Departments	Children
1890–91	11	2,293
1891–92	113	26,674
1892–93	156	40,208
1893–94	183	49,367
1894–95	208	52,982
1895–96	246	62,494
1896–97	364	86,638
1897–98	322	70,626

The last year shows an apparent falling-off in the teaching of this subject, but, as has been mentioned above, the Government having made the giving of object lessons obligatory in the lower standards, 442 Departments, with 75,993 children, have already adopted them. This has caused a reduction in the teaching of 'Elementary Science' under that name; but, taking the two subjects together, this must be regarded as a very considerable gain.

The Education Department continues to meet the objection against the limitation under the Code by which only two class subjects are allowed to be taught, by adding combined courses of study. This year a new course of this character has been introduced into Schedule II., described as 'Elementary Science and Geography Combined.' And as, under the present regulations, one of the class subjects must be such as can be taught by means of object lessons in the lower standards, some such subject as the combined one above mentioned must be taken. A copy of the scheme is given in the Appendix, by which it will be seen that in the lower standards the phenomena of the land and water are to be illustrated experimentally as an introduction to Geographical Science.

A similar principle has been adopted in respect of the specific subjects. Hitherto Chemistry has formed a course of itself, and Physics has been divided into two separate courses, the one dealing with Sound, Light, and Heat, and the other with Magnetism and Electricity; but they formed only three out of the nineteen subjects from which choice could be made.

A separate course of Elementary Physics and Chemistry combined has now been introduced, which is set out in the Appendix, and which is admirably adapted for experimental investigation at the hands of the students themselves.

The work under the Evening Continuation Schools Code continues to progress, as will be seen from the following table :—

Science Subjects	Units for Payment							
	England and Wales				London School Board			
	1893–4	1894–5	1895–6	1896–7	1893–4	1894–5	1895–6	96 –7
Euclid . . .	595	1,086	1,648	2,270	10	29	7	—
Algebra . . .	3,940	6,657	10,374	14,260	316	302	535	714
Mensuration . .	14,521	32,931	41,772	50,748	279	374	452	369
Elementary Physiography	2,554	4,045	6,590	6,325	37	9	5	—
Elementary Physics and Chemistry	6,500	7,850	6,749	5,183	79	200	152	129
Science of Common Things	6,223	10,350	12,906	18,293	231	262	468	556
Chemistry . .	3,484	7,814	8,222	9,641	212	455	404	488
Mechanics . .	841	1,148	1,458	2,196	230	197	209	127
Sound, Light, and Heat	500	1,046	861	1,156	—	15	11	7
Magnetism and Electricity	2,359	4,451	5,073	6,990	662	776	783	939
Human Physiology .	5,695	8,395	7,825	10,047	91	68	56	49
Botany . . .	336	547	905	1,080	5	91	97	32
Agriculture . .	3,579	4,991	4,694	4,061	—	—	—	—
Horticulture . .	438	1,140	1,812	1,911	—	—	—	—
Navigation . .	42	69	142	99	—	—	—	—
Totals . .	51,607	92,520	111,031	134,260	2,152	2,778	3,179	3,410

It is again evident that the mathematical subjects are rapidly increasing in favour, and that Agriculture is decreasing. It will be noticed with satisfaction that the Science of Common Things is receiving greatly increased attention, but it is a matter of regret that there is a decrease in the time given to Elementary Physiography, and still more so in the case of Elementary Physics and Chemistry. Agriculture would become a more valuable and probably a more popular subject of study if a really good practical course were devised.

An important change has been taking place in Scotland. The code of the Scotch Education Department now admits of the possibility of gaining the full class grant although only two subjects are taken. As one of these must be English, and in the higher standards provision must be made for history or geography. or both, the teaching of science as a class subject has been greatly reduced during the last two years. But a new article in the Code for 1895 offers a special grant of a shilling on the average attendance of boys who are satisfactorily taught 'elementary science'; and this has far more than made up the deficiency. In fact the aggregate total of children learning elementary science in the Scotch schools has risen from 34,151 in 1894–95 to 85,671 and 133,855 respectively in the two succeeding years.

Your Committee have frequently referred to the anomaly that pupil teachers are not obliged to receive any instruction in Natural Science, although they may have to give instruction in such subjects, either specifically or in the form of object lessons ; indeed, if they should be in charge of a class of the three lower standards it would be obligatory upon them to give such object lessons. A Departmental Committee, consisting of the Rev. T. W. Sharpe, Her Majesty's Chief Inspector of Schools, as Chairman, and several Inspectors and Principals of Training Colleges and Pupil-teacher Centres, have reported upon the pupil-teacher system. They recommend that the age for entering as pupil teachers should be raised, and that the interval between the elementary school and their apprenticeship should be passed at a secondary school. This would by no means ensure that the young people would receive any instruction in Science during that period of their career. No alteration is proposed in the optional Science Course prescribed by the Code of the Education Department, except that the Queen's Scholarship examination is to be limited to the elementary stage of Physiography prescribed in the syllabus of the Science and Art Department. With regard to the College Course the recommendation is singularly weak, Science being placed as an optional subject, without any definite course of study prescribed. For the first two years it is laid down that of the optional subjects not more than two must be taken out of a list of four or six respectively, some of which from their very nature are almost sure to be taken in preference.

An important letter has been addressed to the Right Hon. Sir John Gorst by Sir Philip Magnus, the Chairman of the Joint Scholarship Board, in conjunction with the Chairmen of its four educational committees. They point out the necessity of securing the proper training of those who will be teachers of scientific subjects, and that the instruction of pupil-teachers in science is now often carried on, under great pressure, by a system of cram, and even by persons who have not themselves any satisfactory knowledge of modern scientific methods. They suggest as a remedy that the first part only of the elementary stage, Physiography, be compulsory ; that the teaching of this subject be recognized only where it is given with proper accessories, all pupils performing the experiments in a series of at least twenty-four lessons of two hours' duration; and that inspectors should be required particularly to report whether proper apparatus and accessories are provided.

In last year's report your Committee referred to what Mr. Heller was doing in respect of the teaching of Science in the schools of the London School Board. He has since obtained a better appointment at Birmingham, but the syllabus of lessons which he prepared is still employed in the schools. This of course requires that the masters and mistresses should be qualified for carrying it out, and for this purpose classes of twenty-four hours are conducted for their benefit by the Science Demonstrators. These gentlemen have lately agreed upon two separate syllabuses for masters and mistresses, which follow in general the scheme they are expected to teach to their scholars. The classes of a similar kind that have been carried on hitherto have been appreciated by the teachers, and the Board are increasing their laboratory and other accommodation for the purpose. It is recognised that it will be necessary to continue these teachers' courses for some years, in order to overcome the difficulty which now exists in consequence of the general want of practical experiment in such instruction in Science as has been given in the course of training of most class teachers.

APPENDIX.

Schedule II.—*Course* D. '*Elementary Science and Geography combined.*'

Standards I., II., *and* III.—Annual courses of about thirty object lessons, of which elementary geography should form a part, beginning with the simplest phenomena which the children can observe :—land, water, the form of the earth, the sea, hills, valleys, rivers, proceeding to notions of locality and distance, and the means of representing all of these by modelling in sand or other material, and by a map, with special reference to the map of England.

The other object lessons should include some of the various subjects suggested in this Schedule under the head of Elementary Science.

Standard IV.—Geography of England, physical and political.

Lessons on animals and on materials used in agriculture, or in some simple manufactures.

Standard V.—Geography of the British Isles, with some knowledge of India, and one or more of the Colonies.

Lessons on means of locomotion, and on processes used in agriculture or manufacture.

Standard VI.—Geography of Europe, physical, political, and commercial.

Lessons on the physical laws that determine climate, animal life, locality of certain industries, &c.

Standard VII.—The work of the preceding years, with special knowledge of the British Empire, and of those portions of the world with which we are engaged in commerce.

Distribution of the races of mankind.

Schedule IV.—*Specific Subjects.* (13.) '*Elementary Physics and Chemistry.*'

1*st Stage.*—Properties of common stuffs ; relative density of solids and liquids ; flotation of solids. The barometer and thermometer ; their use ; graphic representation of daily readings. Solution : water as a solvent ; solubility of metals, &c. in acids ; crystallisation of salt, soda, alum.

2*nd Stage.*—Evaporation and distillation ; heat absorbed in fusion of ice and in conversion of water into steam ; density of ice ; change in density of water on heating ; moisture in air ; wet and dry bulb thermometer. Study of iron rusting, and of combustion of candle, gas, oil, phosphorus ; effect on metals of heating in air ; discovery of active constituent of air.

3*rd Stage.*—Chalk and lime ; the burning of chalk or limestone ; action of muriatic acid on chalk or limestone ; carbonic acid ; reformation of chalk. Discovery of carbonic acid in air ; its formation by combustion of carbonaceous materials and in respiration. Study of action of muriatic and vitriolic acids on zinc ; combustion of the gas obtained, and discovery of the composition of water. Presence of air and solids dissolved in water ; sea water ; hardness of water.

Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor H. McLeod, Professor W. C. Roberts-Austen, Mr. H. G. Madan, *and* Mr. D. H. Nagel.

The collection and verification of titles of papers on spectroscopy is being continued, and a list is appended which brings the catalogue of spectroscopic literature up to the end of 1897.

It is proposed to continue the work of the Committee up to the end of the year 1899, after which date the commencement of the International Catalogue of Scientific Papers will render further procedure on the part of the British Association unnecessary.

The Committee are strongly of opinion that it is most desirable that the separate instalments of the catalogue published at various dates in the Reports of the Association should be (at the conclusion of the work) collected, arranged as one continuous list of papers, and reprinted as a whole.

This would appear to be the only way of obtaining the full value of the catalogue as a work of reference for those engaged on the subject of spectroscopy. One of the members of the Committee is quite willing to undertake the whole work of rearrangement of the matter and passing it through the press. The only question is the expense of printing, which will be certainly not less than 120*l.* Some of this might be met by grants from the Association and from other scientific societies which possess libraries; and, to avoid actual loss, a charge might be made for each copy of the catalogue.

The matter need not be settled until next year, but in the meantime the Committee hope that it will have the earnest consideration of the Association.

The Committee therefore ask to be reappointed.

PAPERS ON SUBJECTS CONNECTED WITH SPECTROSCOPY.

Continuation of the List published in the Report for 1894.

[In cases where it has not been found possible to verify a reference, the latter is placed in brackets, in the same column as the title of the paper. A list of the chief abbreviations used will be found at the end of the catalogue.]

I.

INSTRUMENTAL.

1892.

J. S. Ames . .	The Modern Spectroscope. I. The Concave Grating in Theory and Practice. (Feb.)	'Astron. and Astrophys.' xi. 28–42.
J. E. Keeler . .	The Modern Spectroscope. II. The Star Spectroscope of the Lick Observatory. (Feb.)	'Astron. and Astrophys.' xi. 140–144.
E. C. Pickering .	The Modern Spectroscope. III. The Objective Prism. (March.)	'Astron. and Astrophys.' xi. 199–203.

INSTRUMENTAL, 1892, 1893, 1894.

C. A. Young . .	The Modern Spectroscope. IV. The New Spectroscope of the Halsted Observatory. (April.)	'Astron. and Astrophys.' xi. 292–296.
H. Deslandres .	Spectrograph zur Messung von Sternbewegungen. (Dec.)	'Naturwiss. Rundschau,' vii. 676; 'Beiblätter,' xvii. 448–449 (Abs.)
W. Grosse . .	Spectrophotograph der Pariser Sternwarte. (Dec.)	'Naturwiss. Rundschau,' vii. 676 (Abs.)

1893.

J. E. Keeler . .	The Modern Spectroscope. VI. The Spectroscope of the Alleghany Observatory. (Jan.)	'Astron. and Astrophys.' xii. 40–50.
G. E. Hale . .	The Spectroheliograph. (Feb.) .	'Astron. and Astrophys.' xii. 241 – 257; 'Beiblätter,' xviii. 89 – 90 (Abs.)
L. Becker . .	The Modern Spectroscope. VII. The Spectroscope of the Royal Observatory, Edinburgh. (June.)	'Astron. and Astrophys.' xii. 542–545.
W. Huggins . .	The Modern Spectroscope. VIII. The Tulse Hill Spectroscope. (Sept.)	'Astron. and Astrophys.' xii. 615–619.
H. F. Newall . .	On a Combination of Prisms for a Stellar Spectroscope. (Read Nov. 13.)	'Proc. Phil. Soc. Camb.' viii. 138 – 141; 'Zeitschr. f. Instrumentenkunde,' xiv. 369 – 370; 'Beiblätter,' xix. 323 (Abs.); 'Nature,' xlix. 379 (Abs.)

1894.

L. E. Jewell . .	The Object-glass Grating. (Jan.) .	'Astron. and Astrophys.' xiii. 44 – 48; 'Nature,' xlix. 300–301 (Abs.)
M. T. Edelmann .	Eisendrahtbolometer zur Untersuchung vom Wärmespectrum. (Feb.)	'Electrotech. Zeitschr.' xv. 81–82; 'Beiblätter,' xviii. 749–750 (Abs.)
A. E. Tutton . .	An Instrument of Precision for obtaining Monochromatic Light of any desired Wave-length; and its use in investigating the Optical Characters of Crystals. (Read Feb. 1.)	'Proc. Roy. Soc.' lv. 111–113 (Abs.); 'Beiblätter,' xviii. 835 (Abs.)
N. von Konkoly .	Ein solides lichtstarkes Sternspectroscop. (Mar.)	'Centralzeit. f. Opt. u. Mech.' xv. 61–64.
C. Féry . . .	Réfractomètre à cuve chauffable. Application à la mesure des corps gras. (Read July 30.)	'C. R.' cxix. 332 – 334; 'Beiblätter,' xix. 168 (Abs.)
F. L. O. Wadsworth.	A New Arrangement for Large Spectroscope Slits. (July.)	'Amer. J. Sci.' [3], xlviii. 19 – 20; 'Beiblätter,' xviii. 996 – 997 (Abs.); 'Nature,' l. 326 (Abs.)
” ”	An Improved Form of Littrow Spectroscope. (July.)	'Phil. Mag.' [5], xxxviii. 137 – 142; 'Beiblätter,' xix. 59 (Abs.)

INSTRUMENTAL, 1894.

C. Féry . . .	Application de l'autocollimation à la mesure des indices de réfraction. (Read Aug. 15.)	'C. R.' cxix. 402–404; 'Beiblätter,' xix. 168 (Abs.)
M. Gläser . .	Die Umkehrung der Natriumlinie. (Aug.)	'Zeitschr. f. phys. u. chem. Unterr.' vi. 303; 'Beiblätter,' xviii. 561 (Abs.)
L. Mach . .	Ueber ein Interferenzrefractometer. (Aug.)	'Zeitschr. f. Instrumentenkunde,' xiv. 279–283; 'Proc. Phys. Soc.' xiii. 61 (Abs.)
E. L. Nichols . .	A New Form of Spectrophotometer. (Sept.)	'Phys. Review,' ii. 138–141; 'Beiblätter,' xix. 241–242 (Abs.)
J. Scheiner . .	Ueber neuere Spectroscopconstructionen. (Sept.)	'Zeitschr. f. Instrumentenkunde,' xiv. 316–324; 'Beiblätter,' xviii. 1045 (Abs.); 'Proc. Phys. Soc.' xiii. 60 (Abs.)
H. Crewe and R. Tatnall.	On a Method of Mapping the Spectra of Metals. (Oct.)	'Phil. Mag.' [5], xxxviii. 379–386; 'Beiblätter,' xix. 783 (Abs.)
C. Pulfrich . .	Ueber eine neue Spectroscopconstruction. (Oct.)	'Zeitschr. f. Instrumentenkunde,' xiv. 354–363; 'Proc. Phys. Soc.' xiii. 60 (Abs.); 'Zeitschr. f. anal. Chem.' xxxiv. 744 (Abs.); 'Beiblätter,' xix. 328–329 (Abs.); 'Astrophys. J.' i. 335–349.
F. L. O. Wadsworth.	Ein neuer Spectroscopspalt mit Doppelbewegung. (Oct.)	'Zeitschr. f. Instrumentenkunde,' xiv. 364–366; 'Proc. Phys. Soc.' xiii. 60 (Abs.)
" "	A Spectroscope with Fixed Arms. (Oct.)	'Phil. Mag.' [5], xxxviii. 337–351; 'Beiblätter,' xix. 782–783 (Abs.)
A. König . .	Ein neues Spectrophotometer. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], liii. 786–792; 'Nature,' li. 334 (Abs.); 'Proc. Phys. Soc.' xiii. 64 (Abs.)
N. von Konkoly .	Ein neues photographisches Spectroscop. (Nov.)	'Centralzeit. f. Opt. u. Mech.' xv. 73–74; 'Beiblätter,' xviii. 997 (title).
F. Müller . .	Zur Absorption des Natriumlichts durch Natriumdampf. (Dec.)	'Zeitschr. f. phys. u. chem. Unterr.' viii. 95–96; 'Beiblätter,' xix. 625 (Abs.)
F. L. O. Wadsworth.	The Modern Spectroscope. IX. Fixed-arm Spectroscopes. (Dec.)	'Astron. and Astrophys.' xiii. 835–849; 'Nature,' li. 325 (Abs.)

INSTRUMENTAL, 1895.

A. H. Borgesius .	Beschreibung eines Interferenzrefractometers. Molecularrefraction und Dispersion einiger Salze in Lösungen. (Jan.)	'Verslagen en Mededeelingen d. K. Akad. Amsterdam,' 1894, 1895, 99–103; 'Ann. Phys. u. Chem.' [N.F.], liv. 221–243; 'Beiblätter,' xix. 168–169 (Abs.); 'Proc. Phys. Soc.' xiii. 217–218 (Abs.)
E. L. Nichols . .	A Method for the Study of Transmission Spectra in the Ultra-Violet. (Jan.)	'Phys. Review,' ii. 302–304; 'Beiblätter,' xix. 426 (Abs.); 'Proc. Phys. Soc.' xiii. 169 (Abs.)
F. L. O. Wadsworth.	The Modern Spectroscope. X. General Considerations respecting the Design of Astronomical Spectroscopes. (Jan.)	'Astrophys. J.' i. 52–79.
J. E. Keeler . .	On a Lens for Adapting a Visually-corrected Refracting Telescope to Photographic Observations with the Spectroscope. (Feb.)	'Astrophys. J.' i. 101–111; 'Beiblätter,' xx. 25 (Abs.)
F. L. O. Wadsworth.	The Modern Spectroscope. XI. Some New Designs of Combined Grating and Prismatic Spectroscopes of the Fixed-arm Type; and a New Form of Objective Prism. (Mar.)	'Astrophys. J.' i. 232–260; 'Beiblätter,' xx. 196 (Abs.)
De Thierry . .	Sur un nouvel appareil dit 'héma-spectroscope-comparateur.' (Read April 8.)	'C. R.' cxx. 775–777; 'Zeitschr. f. anal. Chem.' xxxiv. 744 (Abs.); 'Chem. News,' lxxi. 209 (Abs.)
K. Ångström . .	Ueber eine einfache Methode zur photographischen Darstellung des infraroten Spectrums. (Read April 10.) (K. Gesellsch. Wiss. Upsala.)	'J. de Phys.' [3], v. 32 (Abs.); 'Phys. Rev.' iii. 137–141; 'Beiblätter,' xx. 196–197 (Abs.); 'Proc. Phys. Soc.' xiv. 125 (Abs.)
W. Crookes . .	The Slit of a Spectroscope. (April.)	'Chem. News,' lxxi. 175; 'Zeitschr. f. Instrumentenkunde,' xv. 302 (Abs.); 'Beiblätter,' xix. 782 (Abs.)
A. Belopolsky . .	On the Spectrographic Performance of the Thirty-inch Pulkowa Refractor. (May.)	'Astrophys. J.' i. 366–371; 'Beiblätter,' xx. 25 (Abs.)
W. Huggins . .	The Modern Spectroscope. XII. The Tulse Hill Ultra-Violet Spectroscope. (May.)	'Astrophys. J.' i. 359–365.
W. Hallwachs .	Bemerkungen zu einer Arbeit des Hrn. Borgesius über ein Interferenzrefractometer. (June.)	'Ann. Phys. u. Chem.' [N.F.], lv. 282–287.
J. Young and G. R. Darling.	A Method of Transferring Gases to Vacuum Tubes for Spectroscopic Examination. (July.)	'Chem. News,' lxxii. 39; 'J. Chem. Soc.' lxx. II. 3 (Abs.)
C. V. Zenger . .	L'éclipsoscope, appareil pour voir la chromosphère et les protubérances solaires. (Read Sept. 2.)	'C. R.' cxxi. 406–408; 'Nature,' liii. 424 (Abs.)

INSTRUMENTAL, 1895, 1896.

E. Spée . . .	Projet d'une spectroscope réalisant le phénomène d'une éclipse totale du soleil. (Read Oct. 12.) (Oct.)	'Bull. Acad. Belg.' xxx. 274–276; 'Nature,' liii. 309 (Abs.); 'Beiblätter,' xxi. 513 (Abs.)
R. Neumann . .	Schulapparat für Brechung und Zurückverfügung des Lichtes. (Oct.)	'Zeitschr. f. phys. u. chem. Unterr.' viii. 357–358; 'Beiblätter,' xx. 363 (Abs.)
C. Pulfrich . .	Ein neues Refractometer. Universalapparat für refractometrische und spectrometrische Untersuchungen. (Nov.)	'Zeitschr. f. Instrumentenkunde,' xv. 383–394; 'Zeitschr. f. physikal. Chem.' xviii. 294–299; 'J. Chem. Soc.' lxx. II. 161 (Abs.) 'Proc. Phys. Soc.' xiv. 6–7 (Abs.); 'Beiblätter,' xx. 191–192 (Abs.)
F. L. O. Wadsworth.	The Modern Spectroscope. XIII. A New Multiple Transmission Spectroscope of great Resolving Power. (Nov.)	'Astrophys. J.' ii. 265–282.
„ „	The Modern Spectroscope. XIV. Fixed-arm Concave Grating Spectroscopes. (Dec.)	'Astrophys. J.' ii. 370–382.
A. Belopolsky .	Expériment basé sur le principe Doppler-Fizeau.	'Mem. spettr. ital.' xxiii. 123–124; 'Nature,' lii. 515 (Abs.)

1896.

H. Deslandres .	Méthode pour étudier les variations de vitesse radiale des astres avec de faibles instruments. (Jan.)	'Astr. Nachr.' cxxxix. 241–244; 'Beiblätter,' xxi. 343–344 (Abs.)
H. Haga . . .	Eine Aufstellungsweise des Rowland'schen Concavgitters. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], lvii. 389–393; 'Proc. Phys. Soc.' xiv. 123–124 (Abs.)
B. Kolbe . .	Ein handliches Lichtbrechungsapparat. (Jan.)	'Zeitschr. f. phys. u. chem. Unterr.' ix. 20–24.
F. L. O. Wadsworth.	The Modern Spectroscope. XV. On the Use and Mounting of the Concave Grating as an Analysing or Direct Comparison Spectroscope. (Jan.)	'Astrophys. J.' iii. 47–62; 'Beiblätter,' xxi. 334 (Abs.)
A. Belopolsky .	On the Performance of an Auxiliary Lens for Spectrographic Investigations with the 30-inch Refractor of the Pulkowa Observatory. (Feb.)	'Astrophys. J.' iii. 147–149; 'Beiblätter,' xxi. 334 (Abs.)
A. H. Bruère .	A Comparison of Two Concave Rowland Gratings. (Feb.)	'Phys. Review,' iii. 301–305; 'Proc. Phys. Soc.' xiv. (Abs.), 123; 'Beiblätter,' xx. 653 (Abs.)
C. Pulfrich . .	Appareil universel pour les mesures de réfraction et de dispersion (Feb.)	'J. de Phys.' [3], v. 73–79.

INSTRUMENTAL, 1896, 1897.

F. L. O. Wadsworth.	The Modern Spectroscope. XVI. A Simple Optical Device for completely Isolating or Cutting-out any desired Portion of the Diffraction Spectrum, and some further Notes on Astronomical Spectroscopes. (March.)	'Astrophys. J.' iii. 169–192; 'Beiblätter,' xxi. 334–335 (Abs.)
H. F. Newall .	The Modern Spectroscope. XVII. Description of a Spectroscope (the Bruce Spectroscope) recently constructed for use in connection with the 25-inch Refractor of the Cambridge Observatory. (April.)	'Monthly Not. R. A. S.' lvi. 98–110; 'Astrophys. J.' iii. 266–281.
C. Pulfrich . .	A New Form of Refractometer. (April.)	'Astrophys. J.' iii. 259–266.
H. F. Newall. .	On the Spectroscope used in connection with the 25-inch Refractor. (Read May 25.)	'Proc. Phil. Soc. Camb.' ix. 179 (Abs.)
,, . .	A Suggestion for a Form of Spectroheliograph. (Read May 25.)	'Proc. Phil. Soc. Camb.' ix. 179–183.
F. L. O. Wadsworth.	The Modern Spectroscope. XVIII. On the Conditions of Maximum Efficiency in the Use of the Spectrograph. (May.)	'Astrophys. J.' iii. 321–347; 'Beiblätter,' xxi. 335 (Abs.)
H. C. Lord . .	The Spectroscope of the Emerson-McMillin Observatory. (June.)	'Astrophys. J.' iv. 50–53.
G. E. Hale and F. L. O. Wadsworth.	The Modern Spectroscope. XIX. The Objective Spectroscope. (June.)	'Astrophys. J.' iv. 54–78; 'Beiblätter,' xxi. 335–336 (Abs.); 'Nature,' liv. 256 (Abs.)
F. L. O. Wadsworth.	The Modern Spectroscope. XX. On a New Form of Fluid Prism without Solid Walls, and its Use in an Objective Spectroscope. (Nov.)	'Astrophys. J.' iv. 274–277; 'Nature,' lv. 110–111 (Abs.); 'Beiblätter,' xxi. 862 (Abs.)

1897.

W. Huggins . .	On an Automatic Arrangement for giving Breadth to Stellar Spectra on a Photographic Plate. (Jan.)	'Astrophys. J.' v. 8–10; 'Beiblätter,' xxi. 521 (Abs.)
F. Walleraut . .	Sur un appareil permettant de mesurer les indices de réfraction des minéraux des roches. (Read Feb. 8.)	'C. R.' cxxiv. 315–317; 'Chem. Centr.' 1879, I. 663–664 (Abs.); 'Beiblätter,' xxi. 509 (Abs.)
M. Berthelot . .	Nouvel appareil pour l'application de l'analyse spectrale à la reconnaissance des gaz. (Read Mar. 15.)	'C. R.' cxxiv. 525–528; 'Chem. Centr.' 1897, I. 940 (Abs.); 'Nature,' lv. 503 (Abs.); 'Chem. News,' lxxv. 179 (Abs.); 'J. Chem. Soc.' lxxii. 298 (Abs.); 'Ann. Chim. et Phys.' [7], xi. 43–47; 'Beiblätter,' xxi. 514 (Abs.)
G. E. Hale . .	Note on a Form of Spectroheliograph suggested by Mr. H. F. Newall. (March.)	'Astrophys. J.' v. 211–213.

M. Hamy . .	Nouvelle lampe à cadmium pour la production des franges d'interférence, à grande différence de marche. (Read April 5.)	'C. R.' cxxiv. 749–752; 'Chem. News,' lxxv. 202 (Abs.)
C. Leiss . . .	Die neuerere Spectrometermodelle der R. Fuess'schen Werkstätte in Steglitz bei Berlin. (April.)	'Mechaniker,' v. 113-115.
S. F. Burford .	The Oleorefractometer. (May) .	'J. Soc. Chem. Ind.' xvi. 411; 'Chem. Centr.' 1897, II. 232 (Abs.)
F. Dupont . .	Lumière jaune pour polarimètre. (June.)	'Bull. Soc. Chim.' [3], xvii. 584; 'Beiblätter,' xxi. 985 (Abs.)
C. Leiss . . .	Ueber neuere spectrophotographische Apparate. (Nov.)	'Zeitschr. f. Instrumentenkunde,' xvii. 321–334, 357–371; 'Beiblätter,' xxii. 221–222 (Abs.)
P. Fuchs . .	Ueber electrische Entladungsröhren zur wissenschaftlichen Spectralanalyse und deren Herstellung ('Zeitschr. f. Glasinstr.-Industrie,' vi. 174–177, vii. 4–6).	'Beiblätter,' xxii. 218 (titles).
W. Hallwachs .	Differentialspectrometer ('Verh. Ges. Naturforsch. Frankfurt,' 1897, p. 54).	'Beiblätter,' xxi. 730-731 (Abs.)
J. Nulander . .	Sur un spectro-photomètre construit pour distinguer directement les raies telluriques dans le spectre solaire. ('Öfvers. af Finska Vet. Societat Förhandl.' xxxix., 9 pp.)	'Beiblätter,' xxii. [24] (title).

II.

EMISSION SPECTRA.

1885.

S. P. Langley .	Observations on Invisible Heat Spectra, and on the Recognition of hitherto unmeasured Wave-lengths. (Aug.)	'Amer. Assoc. Rep.' 1885, 55–75; 'Phil. Mag.' [5], xxi. 394–409.

1891.

J. M. Eder .	Neue Banden und Linien im Emissionspectrum der Ammoniakoxygenflamme. (Read Mar. 5.)	'Wien. Anz.' xxviii. 44–47; 'Beiblätter,' xvii. 204–206 (Abs.)
W. N. Hartley .	On the Physical Characters of the Lines in the Spark Spectra of the Elements. (Read April 16.)	'Proc. Roy. Soc.' xlix. 448–451; 'Astron. and Astrophys.' 1892, 223–228.
O. Neovius . .	Om skiljandet af knävets och Syrets linien i Luftens Emission-spektrum. (Read Oct. 14.)	'Bihang. till. K. Svensk. Vet. Akad. Handl.' xvii. Afd. I. No. 8, 69 pp.; 'Beiblätter,' xvii. 563–564 (Abs.)

EMISSION SPECTRA, 1892, 1893.

E. Pringsheim .	Das Kirchhoff'sche Gesetz und die Strahlung der Gase. I. Die Strahlung des Natriums. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], xlv. 428–459.
W. L. Dudley .	The Colours and Absorption Spectra of thin Metallic Films and of Incandescent Vapours of the Metals, with some Observations on Electrical Volatility. (March.)	'Amer. Chem. J.' xiv. 185–190; 'J. Chem. Soc.' lxii. 1037 (Abs.); 'Ber.' xxvi. (Ref.), 37–38 (Abs.); 'Zeitschr. anal. Chem.' xxii. 573 (Abs.)
H. Kayser . .	Ueber die Linienspectren der Elementen der ersten und zweiten Gruppe des Mendeléef'schen Systems. (April.)	'Chem. Zeitung.' xvi. 533–534.
B. W. Snow . .	Ueber das ultrarothe Emissionspectrum der Alkalien. (June.)	'Ann. Phys. u. Chem.' [N.F.], xlvii. 208–251; 'J. Chem. Soc.' lxiv. II. 58 (Abs.)
J. M. Eder . .	Beiträge zur Spectralanalyse. I. Ueber das Emissionspectrum der Ammoniakoxygenflamme. II. Ueber die Verwendbarkeit des Funkenspectrums verschiedener Metalle zur Bestimmung der Wellenlänge im Ultraviolette. (Read Nov. 3.)	'Denkschr. Akad. Wien,' lx. 1–24; 'Beiblätter,' xviii. 910–912 (Abs.)
V. Schumann .	Ueber eine neue ultraviolett-empfindliche Platte, und die Photographie der Lichtstrahlen kleinster Wellenlängen. (Read Nov. 10.)	'Wien. Anz.' xxix. 230–231; 'Naturw. Rundschau,' ix. 16 (Abs.); 'Nature,' xlix. 254 (Abs.)
W. N. Hartley .	Methods of observing the Spectra of easily Volatile Metals and their Salts, and of Separating their Spectra from those of the Alkaline Earths. (Read Dec. 1.)	'J. Chem. Soc.' lxiii. 138–141; 'Chem. News,' lxvi. 313 (Abs.)
J. M. Eder and E. Valenta.	Ueber einige neue Linien im brechbarsten ultravioletten Emissionspectrum des metallischen Calciums. (Read Dec. 1.)	'Wien. Anz.' xxix. 252–253.

1893.

J. S. Ames . .	On the Probable Spectrum of Sulphur. (Jan.)	'Astron. and Astrophys.' xii. 50–51; 'Chem. News,' lxvii. 40; 'Ber.' xxvi. (Ref.) 366 (Abs.)
J. M. Eder and E. Valenta.	Ueber das Emissionspectrum der elementaren Silicium, und den spectrographischen Nachweis dieses Elementes. (Read Jan. 19.)	'Wien. Anz.' xxx. (1893), 19–21.
" " .	Ueber das Linienspectrum des elementaren Kohlenstoffes in Inductionsfunken, und über das ultraviolette Funkenspectrum nasser und trockener Holzkohle. (Read Jan. 19.)	'Wien. Anz.' xxx. (1893), 21–24.

EMISSION SPECTRA, 1893.

J. M. Eder and E. Valenta.	Ueber das Emissionspectrum des Kohlenstoffes und Silicium. (Read Jan. 19.)	'Denkschr. Akad. Wien,' lx. 241–263; 'Beiblätter,' xviii. 753–756 (Abs.)
J. Parry	The Spectrum of Iron and the Periodic Law. (Jan.)	'Nature,' xlv. 253–255; 'Beiblätter,' xvii. 748–749 (Abs.)
E. C. C. Baly	Separation and Striation of Rarefied Gases under the Influence of the Electric Discharge. (Read Feb. 10.)	'Proc. Phys. Soc.' xii. 147–153; 'Chem. News,' lxvii. 95 (Abs.)
V. Schumann	The Hydrogen Line, H_β, in the Spectrum of Nova Aurigæ and in the Spectrum of Vacuum Tubes. (Feb.)	'Astron. and Astrophys.' xii. 159–166; 'Nature,' xlvii. 425 (Abs.)
J. M. Eder and E. Valenta.	Ueber das ultraviolette Linienspectrum des elementaren Bor. (Read April 13.)	'Denkschr. Akad. Wien,' lx. 307–311; 'Beiblätter,' xviii. 752–753 (Abs.)
B. Hasselberg	Note on the Spectroscopy of Sulphur. (April.)	'Astron. and Astrophys.' xii. 347–349; 'Beiblätter,' xviii. 86 (Abs.)
E. Pringsheim	Das Kirchhoff'sche Gesetz, und die Strahlung der Gase. II. Die Strahlung von Lithium, Thallium und Kalium. (April.)	'Ann. Phys. u. Chem.' [N.F.], xlix. 347–365.
H. Wilde	The Spectrum of Thallium, and its Relation to the Homologous Spectra of Indium and Gallium. (Read April 20.)	'Proc. Roy. Soc.' liii. 369–372; 'Ber.' xxviii. (Ref.), 218 (Abs.)
J. M. Eder and E. Valenta.	Ueber den Verlauf der Bunsen'schen Flammenreactionen im ultravioletten Spectrum. (Read July 9.)	'Denkschr. Akad. Wien,' (1893), lx. 467–476; 'Beiblätter,' xviii. 909–910 (Abs.)
B. M. Snow	On the Continuous Spectrum of Sodium. (Amer. Assoc. Report.) (Aug.)	'Phys. Review,' i. 296–298; 'Beiblätter,' xviii. 997 (Abs.)
"	On the Continuous Spectrum of the Alkalies [Sodium]. (Aug.)	'Proc. Amer. Assoc.' 1893, 79–80 (Abs.)
"	The Infra-red Spectra of the Alkali Metals. (Nov.)	'Phys. Review,' i. 221–223.
H. C. Vogel	Ueber die Bezeichnung der Linien des I. Wasserstoffspectrums. (Nov.)	'Astr. Nachr.' cxxxiv. 95–96; 'Nature,' xlix. 162; 'Beiblätter,' xviii. 670 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectren der Elemente. VII. Die Spectren von Zinn, Blei, Arsen, Antimon, Wismuth. (Read Dec. 7.)	'Abhandl. Akad. Berlin,' 1893, 21 pp.; 'Ann. Phys. u. Chem.' [N.F.], lii. 93–113; 'Nature,' xlix. 509 (Abs.)
F. Paschen	Ueber die Emission der Gase. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], li. 1–39; 'Nature,' xlix. 376 (Abs.); 'Phil. Mag.' [5], xxxvi. 551–552 (Abs.); 'Proc. Phys. Soc.' xiii. 13 (Abs.)

Emission Spectra, 1894.

M. Eisig	Das Linienspectrum des Sauerstoffes. (March.)	'Ann. Phys. u. Chem.' [N.F.], li. 747–760; 'J. Chem. Soc.' lxvi. II. 265–266 (Abs.)
E. Pringsheim	Bemerkungen zu Hrn. Paschen's Abhandlung 'Ueber die Emission erhitzten Gase.' (March.)	'Ann. Phys. u. Chem.' [N.F.], li. 441–447; 'Nature,' xlix. 547 (Abs.); 'Proc. Phys. Soc.' xiii. 25 (Abs.)
W. N. Hartley	On Variations observed in the Spectrum of Carbon Electrodes, and on the Influence of one Substance on the Spectrum of another. (Received Jan. 13. Read April 19.)	'Proc. Roy. Soc.' lv. 344–349; 'Nature,' l. 141–142 (Abs.); 'J. Chem. Soc.' lxviii. II. 432 (Abs.); 'Beiblätter,' xviii. 1046–1047 (Abs.)
H. Kayser and C. Runge.	Beiträge zur Kenntniss der Linienspectra. (April.)	'Ann. Phys. u. Chem.' [N.F.], li. 114–118.
H. Kayser and C. Runge.	Ueber die Spectra von Zinn, Blei, Arsen, Antimon, Wismuth. (April.)	'Ann. Phys. u. Chem.' [N.F.], lii. 93–118; 'J. Chem. Soc.' lxvi. II. 303–304 (Abs.); 'Nature,' l. 118 (Abs.)
J. R. Rydberg	Beiträge zur Kenntniss der Linienspectren. (April.)	'Ann. Phys. u. Chem.' [N.F.], lii. 119–131.
C. Kirn	Ueber die Aehnlichkeit der Lichtemission einer nachleuchtenden Geissler'schen Röhre mit dem Beginne des Glühens fester Körper. (May.)	'Ann. Phys. u. Chem.' [N.F.], lii. 381–384; 'Proc. Phys. Soc.' xiii. 17 (Abs.); 'Nature,' l. 188 (Abs.)
E. P. Lewis and E. S. Ferry.	The Infra-red Spectrum of the Metals. (May.)	'Johns Hopkins Univ. Circ.' xiii. (No. 112), 74–76; 'Beiblätter,' xix. 242 (Abs.)
C. A. Mebius	Ueber die Glimmentladung in der Luft. (Read May 9.)	'Bihang till K. Svensk. Akad. Handl.' xx. Afd. I. No. 1, 1–38; 'Ann. Phys. u. Chem.' [N.F.], liv. 520–543; 'Nature,' li. 620 (Abs.)
F. Paschen	Ueber die Emission der Gase. (May.)	'Ann. Phys. u. Chem.' [N.F.], lii. 209–237; 'Proc. Phys. Soc.' xiii. 13 (Abs.)
J. M. Eder and E. Valenta.	Ueber das Spectrum des Kaliums, Natriums und Cadmiums bei verschiedenen Temperaturen. (Read June 7.)	'Denkschr. Akad. Wien,' lxi. 347–364; 'Ber.' xxviii. (Ref.), 270 (Abs.)
W. N. Hartley	Flame Spectra at High Temperatures. Part II. The Spectrum of Metallic Manganese, of Alloys of Manganese, and of Compounds containing that Element. (Read June 14.)	'Proc. Roy. Soc.' lvi. 192–193 (Abs.); 'Chem. News,' lxx. 2–4, 15–16; 'Nature,' l. 238 (Abs.); 'J. Chem. Soc.' lxviii. II. 432 (Abs.); 'Beiblätter,' xviii. 997–998 (Abs.)

EMISSION SPECTRA, 1894.

W. N. Hartley	Flame Spectra at High Temperatures. Part III. The Spectroscopic Phenomena and Thermochemistry of the Bessemer Process. (Read June 14.)	'Proc. Roy. Soc.' lvi. 193–199 (Abs.); 'Nature,' l. 261–262 (Abs.); 'J. Chem. Soc.' lxviii. II. 432–433 (Abs.); 'Beiblätter,' xviii. 997–998 (Abs.)
B. Hasselberg	Ueber das Linienspectrum des Sauerstoffs. (June.)	'Ann. Phys. u. Chem.' [N.F.], lii. 758–761.
F. Aymonnet	Sur les radiations calorifiques comprises dans la partie lumineuse du spectre. (Read July 9.)	'C. R.' cxix. 151–154; 'Beiblätter,' xix. 64 (Abs.)
A. de Gramont	Sur le spectre de lignes du soufre, et sur sa recherche dans les composés métalliques. (Read July 2.)	'C. R.' cxix. 68–70; 'Beiblätter,' xviii. 912 (Abs.); 'Chem News,' lxx. 49 (Abs.); 'J. Chem. Soc.' lxvi. II. 434–435 (Abs.)
M. Gläser	Funkenspectra mittels der Influenzmaschine. (Aug.)	'Zeitschr. f. phys. u. chem. Unterr.' vi. 303–304; 'Beiblätter,' xviii. 559 (Abs.)
W. N. Hartley	New Methods of Spectrum Analysis, and on Bessemer Flame Spectra. (Aug.)	'Brit. Assoc. Rep.' 1894, 610–611; 'Beiblätter,' xx. 26 (Abs.)
G. D. Liveing and J. Dewar.	Preliminary Note on the Spectrum of the Electric Discharge in Liquid Oxygen, Air, and Nitrogen. (Aug.)	'Phil. Mag.' [5], xxxviii. 235–240; 'J. Chem. Soc.' lxviii. II. 33–34 (Abs.); 'Ber.' xxviii. (Ref.), 4–5 (Abs.); 'Beiblätter,' xix. 60 (Abs.)
F. Paschen	Die genauen Wellenlängen der Banden des ultrarothen Kohlensäure- und Wasserspectrums. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], liii. 334–336; 'Proc. Phys. Soc.' xiii. 15 (Abs.)
L. Thomas	Sur la constitution de l'arc électrique. (Read Oct. 29.)	'C. R.' cxix. 728–730; 'Nature,' li. 47 (Abs)
E. Köttgen	Untersuchungen der spectralen Zusammensetzung verschiedener Lichtquellen. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], liii. 793–811; 'Nature,' li. 334 (Abs.)
F. Paschen	Notiz über die Gültigkeit des Kirchhoff'schen Gesetzes von der Emission. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], li. 40–46; 'Proc. Phys. Soc.' xiii. 13 (Abs.)
B. Hasselberg	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. I. Spectrum des Chroms.	'Handl. K. Svens. Vet. Akad.' xxvi. 32 pp.; 'Beiblätter,' xviii. 837 (Abs.)
V. Schumann	Vom Wasserstoffspectrum	'Jahrb. f. Photogr.' viii. 59–64; 'Beiblätter,' xviii. 752 (Abs.)

EMISSION SPECTRA, 1895.

Lord Rayleigh and W. Ramsay.	Argon, a New Constituent of the Atmosphere. (Read Jan. 31.)	‘Phil. Trans.’ clxxxvi. A. 187–141; ‘Proc. Roy. Soc. lvii. 265–287; ‘Chem. News,’ lxxi. 51–59; ‘Zeitschr. f. physikal. Chem.’ xvi. 344–369; ‘Beiblätter,’ xix. 276–279 (Abs.); ‘J. Chem. Soc.’ lxx. II. 99–106 (Abs.)
W. Crookes . .	On the Spectra of Argon. (Read Jan. 31.)	‘Phil. Trans.’ clxxxvi. A. 243–251; ‘Proc. Roy. Soc.’ lvii. 287–289; ‘Chem. News,’ lxxii. 66–69; ‘Zeitschr. f. physikal. Chem.’ xvi. 369–379; ‘Ber.’ xxviii. (Ref.), 176 (Abs.); ‘Beiblätter,’ xix. 331–332 (Abs.)
W. N. Hartley .	On the Spark Spectrum of Argon as it appears in the Spark Spectrum of Air. (Read Jan. 31.)	‘Proc. Roy. Soc.’ lvii. 293–296; ‘Beiblätter,’ xix. 625 (Abs.)
H. A. Rowland and R. R. Tatnall.	The Arc Spectra of the Elements. I. Boron and Beryllium. (Jan.)	‘Astrophys. J.’ i. 14–17; ‘Beiblätter,’ xix. 424 (Abs.)
B. Hasselberg .	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. II. Spectrum des Titans. (Read Feb. 13.) (‘Handl. K. Svensk. Vet. Akad.’ xxviii. No. 1, pp. 32).	‘Beiblätter,’ xx. 304 (Abs.)
G. W. A. Kahlbaum	Ueber den neuentdeckten Bestandtheil der Atmosphäre, das Argon. (Feb.)	‘Verh. naturf. Gesellsch. d. Basel,’ xi. 151–173; ‘Beiblätter,’ xix. 461 (Abs.)
H. F. Newall . .	Note on the Spectrum of Argon. (Read Feb. 21.)	‘Proc. Roy. Soc.’ lvii. 346–350; ‘Nature,’ li. 454; ‘Chem. News,’ lxxi. 115–116; ‘Astrophys. J.’ i. 372–376; ‘Ber.’ xxviii. (Ref.), 838 (Abs.)
H. A. Rowland and R. R. Tatnall.	The Arc Spectra of the Elements. II. Germanium.	‘Astrophys. J.’ i. 149–153; ‘Beiblätter,’ xx. 29 (Abs.)
E. C. C. Baly . .	A Possible Explanation of the Twofold Spectra of Oxygen and Nitrogen. (Read March 21.)	‘Proc. Roy. Soc.’ lvii. 468–469; ‘Chem News,’ lxxi. 169–170 (Abs.); ‘Nature,’ li. 550 (Abs.); ‘J. Chem. Soc.’ lxviii. II. 469 (Abs.)
M. Berthelot .	Sur l’argon et sur l’hélium. (Read March 25.)	‘C. R.’ cxx. 660–661; ‘Ber.’ xxviii. (Ref.), 318 (Abs.); ‘Nature,’ li. 552 (Abs.); ‘Chem. News,’ lxxi. 176.

EMISSION SPECTRA, 1895.

W. Crookes	The Spectrum of the New Gas from Clèveite. (Read March 27.)	'J. Chem. Soc.' lxvii. 1108–1109; 'Chem.' News,' lxxi. 151; 'Ber. xxviii. (Ref.), 839 (Abs.); 'Beiblätter,' xix. 624 (Abs.); 'Nature,' li. 543–544; 'Proc. Chem. Soc.' xi. 60–61.
W. Ramsay	Discovery of Helium in Clèveite. (Read March 27.)	'Proc. Chem. Soc.' No. 150, 59–60; 'Chem. News,' lxxi. 151.
,,	Terrestrial Helium. (Read March 27.)	'Proc. Chem. Soc.' No. 150, 59–60; 'Nature,' li. 512, 543.
H. W. Vogel	Ueber das sogenannte künstliche Spectrum von Charles E. Benham. (Read March 8.)	'Verhandl. phys. Gesellsch. Berl.' xiv. 45–47.
P. T. Clève	Sur la présence de l'hélium dans la clèvéite. (Read April 16.)	'C. R.' cxx. 834; 'Beiblätter,' xix. 568 (Abs.); 'J. Chem. Soc.' lxviii. II. 347 (Abs.)
A. de Gramont	Sur les spectres de sélénium et de quelques séléniures naturels. (Read April 8.)	'C. R.' cxx. 778–780; 'Ber.' xxviii. (Ref.), 320 (Abs.); 'Beiblätter,' xix. 566 (Abs.); 'J. Chem. Soc.' lxviii. II. 338 (Abs.)
J. N. Lockyer	On the New Gas obtained from Uraninite. Notes I., II., III. (Read April 25, May 9.)	'Proc. Roy. Soc.' lviii. 67–70, 113–119; 'Beiblätter,' xix. 729 (Abs.); 'Nature,' lii. 8, 55–56; 'Chem. News,' lxxi. 295; 'Ber.' xxix. (Ref.), 161 (Abs.)
W. Ramsay	On a Gas showing the Spectrum of Helium, the reputed cause of D_3, one of the Lines of the Coronal Spectrum. Preliminary Note. (Read April 25.)	'Proc. Roy. Soc.' lviii. 65–67; 'Chem. News,' lxxi. 211; 'Ber.' xxviii. (Ref.), 839 (Abs.); 'Nature,' lii. 7.
Lord Rayleigh	On Argon. (Lecture at Royal Institution, April 5.)	'Chem. News,' lxxi. 299–302, 310–312; 'Nature,' lii. 159–164.
J. S. Ames	The Spectrum Researches of Professor J. M. Eder and E. Valenta. (May.)	'Astrophys. J.' i. 443–446; 'Nature,' lii. 275–276.
J. Evershed	Experiments on the Radiation of Heated Gases. (May.)	'Phil. Mag.' [5], xxxix. 460–476.
W. R. E. Hodgkinson.	Argon in Minerals. (May)	'Chem. News,' lxxi. 248; 'Beiblätter,' xix. 597–598 (Abs.)
L. Palmieri	A proposito della riga dell' Helium apparsa nello spettro di una sublimazione vesuviana nel 1881, ed ora riveduta da Ramsay e da Clève nella Clevite o Clèveite. (Read May 4.)	'Rend. R. Accad. Napoli,' [3], i. 121–122; 'Beiblätter,' xx. 531 (Abs.)

EMISSION SPECTRA, 1895.

J. N. Lockyer	Sur l'analyse spectrale des gaz dégagés par divers minéraux. (Read May 20.)	'C. R.' cxx. 1103–1104; 'Beiblätter,' xix. 566–567 (Abs.); 'Ber.' xxviii. (Ref.), 592 (Abs.); 'J. Chem. Soc.' lxviii. II. 430–431 (Abs.); 'Proc. Phys. Soc.' xiii. 341 (Abs.); 'Chem. News,' lxxi. 281 (Abs.)
W. Ramsay	Sur l'argon et l'hélium. (Read May 13.)	'C. R.' cxx. 1049–1050; 'Chem. News,' lxxi. 259 (Abs.); 'Nature,' lii. 96 (Abs.); 'Beiblätter,' xix. 531 (Abs.); 'Ber.' xxviii. (Ref.), 448 (Abs.)
W. Ramsay and J. N. Collie.	Argon in Minerals. (May)	'Chem. News,' lxxi. 268; 'Beiblätter,' xix. 597–598 (Abs.)
W. Ramsay, J. N. Collie, and M. Travers.	Helium, a Gaseous Constituent of Certain Minerals. Part 1. (Read May 2.)	'Proc. Roy. Soc.' lviii. 81–89; 'J. Chem. Soc.' lxviii. 684–701; 'Beiblätter,' xix. 673–674 (Abs.); 'Nature,' lii. 55 (Abs.)
C. Runge	The Short Wave-lengths of the Spark Spectrum of Aluminium. (May.)	'Astrophys. J.' i. 433.
„	On the Line Spectra of the Elements. (May.)	'Nature,' lii. 106–108; 'Beiblätter,' xx. 530–531 (Abs.)
A. Schuster	Sur les spectres cannelés. (Read May 6.)	'C. R.' cxx. 987–989; 'Beiblätter,' xix. 788–789 (Abs.); 'Proc. Phys. Soc.' xiii. 306 (Abs.)
B. Brauner	Note on Gases of the Helium and Argon Type. (June.)	'Chem. News,' lxxi. 271; 'J. Chem. Soc.' lxviii. II. 347 (Abs.); 'Ber.' xxviii. (Ref.), 904–905 (Abs.); 'Beiblätter,' xix. 675 (Abs.)
H. Deslandres	Découverte d'une troisième radiation permanente de l'atmosphère solaire dans le gaz de la clèvéite. (Read June 17.)	'C. R.' cxx. 1331–1333; 'Ber.' xxviii. (Ref.), 1045 (Abs.); 'Beiblätter,' xix. 693 (Abs.); 'Chem. News,' lxxii. 12 (Abs.); 'Proc. Phys. Soc.' xiii. 340 (Abs.); 'Nature,' lii. 216 (Abs.)
„	Étude spectrale des charbons du four électrique. (Read June 10.)	'C. R.' cxx. 1259–1260; 'Chem. News,' lxxii. 9; 'Proc. Phys. Soc.' xiii. 344 (Abs.); 'Nature,' lii. 192 (Abs.)

Emission Spectra, 1895.

J. N. Lockyer .	On the New Gas obtained from Uraninite. Notes IV. V. (Read June 13.)	'Proc. Roy. Soc.' lviii. 191–195; 'Nature,' lii. 214; 'Chem. News,' lxxii. 4–5, 271–272, 283; 'Beiblätter,' xix. 825 (Abs.); 'Ber.' xxix. (Ref.), 161 (Abs.)
C. J. Lundström .	Flame Spectra observed at Swedish Bessemer Works. (Read June 20; revised Oct. 18.)	'Proc. Roy. Soc.' lix. 76–98; 'Beiblätter,' xx. 367 (Abs.)
W. Ramsay, J. N. Collie, and M. Travers.	Helium, a Constituent of Certain Minerals. (Read June 20.)	'J. Chem. Soc.' lxvii. 684–701; 'Nature,' lii. 306–308, 331–334.
C. Runge . .	Terrestrial Helium. (June) . .	'Nature,' lii. 128; 'Chem. News,' lxxi. 283; 'Beiblätter,' xix. 624–625 (Abs.)
C. Runge and F. Paschen.	Ueber das Spectrum des Helium. (Read June 20.)	'Sitzungsb. Akad. Berlin,' xxx. 639–643; 'Beiblätter,' xix. 884–885 (Abs.); 'Proc. Phys. Soc.' xiii. 345–346 (Abs.)
J. M. Eder and E. Valenta.	Ueber die verschiedenen Spectren des Quecksilbers. (Read July 5.)	'Denkschr. Akad. Wien,' lxi. 401–430; 'Ann. Phys. u. Chem.' [N.F.], lv. 479–502; 'J. Chem. Soc.' lxx. II. 2–3 (Abs.); 'Ber.' xxviii. (Ref.), 270 (Abs.); 'Proc. Phys. Soc.' xiv. 47 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectren der Elemente. I. Mittheilung. (Read July 11.)	'Sitzungsb. Akad. Wien,' civ. Abth. II.a, 909–962; 'Beiblätter,' xx. 693 (Abs.); 'Proc. Phys. Soc.' xiv. 238 (Abs.)
W. Huggins . .	Helium. (July)	'Chem. News,' lxxii. 27; 'Beiblätter,' xix. 730 (Abs.)
F. Paschen . .	Ueber Gesetzmässigkeiten in dem Spectren fester Körper und über eine neue Bestimmung der Sonnentemperatur. (Read July 6.)	'Gött. Nachr.' 1895, No. 3, 294–305.
W. Ramsay . .	Argon and Helium in Meteoric Iron. (July.)	'Nature,' lii. 224–225; 'Beiblätter,' xix. 729 (Abs.)
C. Runge and F. Paschen.	Ueber die Bestandtheile des Clèveitgases. (Read July 11.)	'Sitzungsb. Akad. Berlin,' xxx. 759–763; 'Beiblätter,' xix. 885–886 (Abs.); 'Phil. Mag.' [5], xxxix. 297–303; 'Chem. News,' lxxii. 181–182 (Abs.); 'Proc. Phys. Soc.' xiii. 393–394 (Abs.); 'Nature,' lii. 520–522 (Abs.)
H. Crew and O. H. Rasquin.	Note on the Spectrum of Carbon. (Aug.)	'Astrophys. J.' ii. 103–105.

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H. Crew and O. H. Rasquin.	Note on the Magnesium Band at =5007. (Aug.)	'Astrophys. J.' ii. 100–102; 'Beiblätter,' xx. 30 (Abs.)
W. Crookes . .	The Spectrum of Ramsay's Compound of Argon and Carbon. (Aug. 11.)	'Chem. News,' lxxii. 99; 'J. Chem. Soc.' lxx. II. 2 (Abs.); 'Ber.' xxviii. (Ref.), 840 (Abs.)
,, . .	The Spectrum of Helium. (Aug.)	'Chem. News,' lxxii. 87–89; 'Nature,' lii. 428–430; 'J. Chem. Soc.' lxx. II. 1 (Abs.); 'Ber.' xxviii. (Ref.), 840 (Abs.); 'Proc. Phys. Soc.' xiv. 161–162 (Abs.); 'Zeitschr. anal. Chem.' xi. 6–13.
W. N. Hartley .	On the Thermo-Chemistry of the Bessemer Process. (Read Aug. 7.)	'Journ. Iron and Steel Inst.' xlviii. 95–121; 'Nature,' lii. 426–427 (Abs.)
H. Kayser . .	The Blue Spectrum of Argon. (Aug.)	'Chem. News,' lxxii. 99–100; 'J. Chem. Soc.' lxx. II. 2 (Abs.); 'Ber.' xxviii. (Ref.), 840 (Abs.)
,,	Note on Helium and Argon. (Aug.)	'Chem. News,' lxxii. 89; 'Ber.' xxviii. (Ref.), 840 (Abs.); 'J. Chem. Soc.' lxx. II. 19–20 (Abs.)
H. F. Reid . .	Preliminary Note on the Radiation of Incandescent Platinum. (Aug.)	'Astrophys. J.' ii. 160–161; 'Beiblätter,' xx. 27–28 (Abs.)
W. Le Conte Stevens	Recent Progress in Optics. (Aug.)	'Amer. J. Sci.' l. 277–286, 377–386; 'Nature,' liii. 233–238.
E. Wiedemann and G. C. Schmidt.	Ueber Lichtemission organischer Substanzen im gasförmigen, flüssigen und festen Zustand. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], lvi. 18–26; 'Nature,' lii. 611 (Abs.); 'Proc. Phys. Soc.' xiii. 471–472 (Abs.); 'J. Chem. Soc.' lxx. II. 86–87 (Abs.)
L. J. Troost and V. R. Ouvrard.	Sur la combinaison du magnésium avec l'argon et avec l'hélium. (Read Sept. 2.)	'C. R.' cxxi. 394–395; 'J. Chem. Soc.' lxx. II. 99 (Abs.)
J. M. Eder and E. Valenta.	Ueber das rothe Spectrum des Argons. (Read Oct. 24.)	'Sitzungsb. Akad. Wien,' civ. 218–220; 'Monats. f. Chem.' xvi. 893–895; 'Ber.' xxix. (Ref.), 7–8 (Abs.); 'Beiblätter,' xx. 126 (Abs.); 'Chem. News,' lxxii. 289–290.
J. N. Lockyer .	The New Mineral Gases. (Oct.) .	'Nature,' lii. 547–549.
F. Paschen . .	On the Existence of Law in the Spectra of Solid Bodies and on a New Determination of the Temperature of the Sun. (Oct.)	'Astrophys. J.' ii. 202–211; 'Nature,' liii. 38 (Abs.)

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H. A. Rowland and R. R. Tatnall.	The Arc Spectra of the Elements. III. Platinum and Osmium. (Oct.)	'Astrophys. J.' ii. 184–188; 'Beiblätter,' xx. 365 (Abs.)
H. Wilde	Helium and its Place in the Natural Classification of Elementary Substances. (Read Oct. 1.)	'Phil. Mag.' [5], xl. 466–471; 'J. Chem. Soc.' lxx. II. 165–166 (Abs.)
C. Bohn	Ueber Flammen und leuchtende Gase. (Nov.)	'Zeitschr. f. physikal. Chem.' xviii. 219–239; 'Beiblätter,' xx. 276 (Abs.); 'Proc. Phys. Soc.' xiv. 2–3 (Abs.)
H. Crew	Photographic Maps of Metallic Spectra. (Nov.)	'Astrophys. J.' ii. 318–320.
J. M. Eder and E. Valenta.	Ueber die Spectren von Kupfer, Silber und Gold. (Read Nov. 7)	'Denkschr. Akad. Wien,' lxiii. 189–235; 'Beiblätter,' xx. 366 (Abs.)
A. de Gramont	Sur l'analyse spectrale directe des composés solides, et plus spécialement des minéraux. (Nov.)	'C. R.' cxxi. 121–123; 'Bull. Soc. Chim.' [3], xiii.–xiv. 945–947; 'Ber.' xxviii. (Ref.), 1048 (Abs.)
E. A. Hill	Additional Notes on Argon and Helium. (Nov.)	'Amer. J. Sci.' l. 359–376.
A. Killas and W. Ramsay.	Examination of Gases from Certain Mineral Waters. (Read Nov. 28.)	'Proc. Roy. Soc.' lix. 68–69; 'Nature,' liii. 191; 'Chem. News,' lxxii. 295.
J. N. Lockyer	On the Gases obtained from the Mineral Eliasite. (Read Nov. 21.)	'Proc. Roy. Soc.' lix. 1–3; 'Nature,' liii. 190–191; 'Chem. News,' lxxii. 283; 'Beiblätter,' xx. 314 (Abs.)
,,	On the New Gas obtained from Uraninite. Note VI. (Read Nov. 21.)	'Proc. Roy. Soc.' lix. 4–8; 'Nature,' liii. 163–164 (Abs.); 'Chem. News,' lxxii. 271–272; 'Beiblätter,' xx. 314 (Abs.)
G. J. Stoney	On Prof. Runge and Paschen's Photographs of the Spectrum of the Gas from Clèveite. (Read before Phys. Soc. Nov. 22.)	'Nature,' liii. 94–95 (Abs.); 'Chem. News,' lxxii. 266–267 (Abs.)
A. A. Michelson	On the Broadening of Spectral Lines. (Nov.)	'Astrophys. J.' ii. 251–263; 'Beiblätter,' xx. 532–533 (Abs.)
A. Schuster	On the Evidence to be gathered as to the Simple or Compound Character of a Gas from the Constitution of its Spectrum. (Nov.)	'Chem. News,' lxxii. 224.
E. Wiedemann and G. C. Schmidt.	Spectralbeobachtungen an verdünnten Dämpfen von Metallen und Verbindungen. (Read Nov. 12.)	'Sitzungsb. phys. med. Soc. Erlangen,' xxvii. 127–144; 'Beiblätter,' xx. 693–694 (Abs.); 'Naturw. Rundschau,' xi. 429–431 (Abs.)

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J. M. Eder and E. Valenta.	Ueber die verschiedene Spectren des Argons. (Vorläufige Mittheilung). (Read Dec. 19.)	'Sitzungsb. Akad. Wien,' civ. Abt. II.a, 1171–1177; 'Monatsh. f. Chem.' xvii. 50–56; 'Ber.' xxix. (Ref.), 341 (Abs.); 'Beiblätter,' xx. 531–532 (Abs.); 'J. Chem. Soc.' lxx. II. 405 (Abs.); 'Proc. Phys. Soc.' xiv. 236–27 (Abs.)
S. Friedländer	Ueber Argon. (Dec.) . . .	'Zeitschr. f. physikal. Chem.' xix. 657–667; 'Beiblätter,' xx. 775 (Abs.); 'J. Chem. Soc.' lxx. II. 457 (Abs.); 'Chem. News,' lxxiv. 179–180 (Abs.)
Ch. Moureu .	Sur la présence de l'argon et de l'hélium dans une source d'azote naturelle. (Read Dec. 2.)	'C. R.' cxxi. 819–820; 'Chem. News,' lxxii. 310.
R. Nasini and F. Anderlini.	Sopra alcuni fatti relativi all' argon. (Read Dec. 1.)	'Rend. R. Accad. d. Lincei,' [5], iv. II. Sem. 269–290; 'Beiblätter,' xx. 315 (Abs.)
E. Demarçay .	Spectres électriques. (Texte 91 pp., Planches 20.)	
J. M. Eder . .	Ueber ultravioletten Absorptions- und Emissionsspectren ('Verh. Ges. Naturf. u. Aerzte,' II. 1. Hälfte (1895), 78).	'Beiblätter,' xix. [58] (title).
O. Postma .	Einiges über Ausstrahlung und Absorption. (Inaug.-Diss. Amsterdam, 1895, 94 pp.)	'Beiblätter,' xxii. 98 (Abs.)

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W. Crookes .	Das Spectrum des Heliums . .	'Zeitschr. f. anorg. Chem.' xi. 6–13; 'Beiblätter,' xx. 275–276 (Abs.)
J. M. Eder . .	Bemerkung zu Herren C. Bohn's Abhandlung 'Ueber Flammen und leuchtende Gase.' (Jan.)	'Zeitschr. f. physikal. Chem.' xix. 20–24; 'Beiblätter,' xx. 276–277. (Abs.)
C. Runge and F. Paschen.	On Crookes's Spectrum of Helium. (Jan.)	'Nature,' liii. 245; 'Beiblätter,' xxi. 633 (Abs.)
W. A. Tilden .	An Attempt to Determine the Condition in which Helium and the Associated Gases exist in Minerals. (Read Jan. 23.)	'Proc. Roy. Soc.' lix. 218–224.
J. N. Collie and W. Ramsay.	On the Behaviour of Argon and Helium when submitted to the Electric Discharge. (Read Feb. 13.)	'Proc. Roy. Soc.' lix. 257–270.
W. J. Humphreys and J. F. Mohler.	Effect of Pressure on the Wave-lengths of Lines in the Arc Spectra of Certain Elements. (Feb.)	'Astrophys. J.' iii. 114–118; 'Beiblätter,' xx. 533 (Abs.)

EMISSION SPECTRA, 1896.

H. Kayser . .	Die Fortschritte der Spectroscopie. (Feb.)	'Chem. Zeitung,' xx. 195–196; 'Chem. News,' lxxiv. 307–309.
J. Landauer . .	Die Spectral-Analyse. (Braunschweig, 174 pp.) (Feb.)	'Chem. News,' lxxiii. 70–71 (Review).
C. W. Baldwin .	A Photographic Study of Arc Spectra. I. (March.)	'Phys. Review,' iii. 370–380; 'Beiblätter,' xx. 774 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente, II. III. IV. (Read March 19.)	'Sitzungsb. Akad. Wien,' cv. II.a, 389–436, 503–574, 707–740.
A. Gamgee . .	On the Relations of Turacin and Turacoporphyrin to the Colouring Matter of the Blood. (Read March 19.)	'Proc. Roy. Soc.' lix. 339–342.
E. Haschek . .	Ueber die ultravioletten Funkenspectra der Elemente. (Read March 19.)	'Wien. Anz.' xxxiii. 75–76 (Abs.)
J. N. Lockyer .	On the New Gas obtained from Uraninite. (Seventh Note.) Remarks on Messrs. Runge and Paschen's Diffusion Experiment. (Read March 19.)	'Proc. Roy. Soc.' lix. 342–343; 'Beiblätter,' xx. 775–776 (Abs.)
W. Ramsay . .	Helium, a Gaseous Constituent of Certain Minerals. Part II. Density. (Read March 19.)	'Proc. Roy. Soc.' lix. 325–330.
W. N. Hartley .	The Determination of the Composition of a 'White Sou' by a Method of Spectrographic Analysis. (Read April 23.)	'J. Chem. Soc.' lxix. 842–844; 'Chem. News,' lxxiii. 229 (Abs.)
H. A. Rowland and R. R. Tatnall.	The Arc Spectra of the Elements. IV. Rhodium, Ruthenium, and Palladium. (April.)	'Astrophys. J.' iii. 286–291.
W. N. Hartley and H. Ramage.	On the Occurrence of the Element Gallium in the Clay Ironstone of the Cleveland District of Yorkshire. (Preliminary Notice.) (Read May 7.)	'Proc. Roy. Soc.' lx. 35–37.
H. Kayser . .	Ueber die Spectren des Argons. (Read May 7.)	'Sitzungsb. Akad. Berl.' 1896, 551–564; 'Astrophys. J.' iv. 1–17; 'Beiblätter,' xx. 976 (Abs.)
J. F. Mohler and L. E. Jewell.	On the Wave-lengths of some of the Helium Lines in the Vacuum Tube, and of D_3 in the Sun. (May.)	'Astrophys. J.' iii. 351–355.
J. M. Eder and E. Valenta.	Spectralanalytische Untersuchungen des Argons. (Read June 11.) ('Denkschr. Akad. Wien,' lxiv. 39 pp.) (June.)	'Wien. Anz.' xxxiii. 161 (Abs.); 'Beiblätter,' xxi. 129 (Abs.)
A. de Gramont .	Spectres de dissociation des sels fondus, métaux alkalins, sodium, potassium, lithium. (Read June 15.)	'C. R.' cxxii. 1411–1413; 'Beiblätter,' xx. 693 (Abs.); 'Chem. News,' lxxiv. 12 (Abs.)

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A. de Gramont .	Sur le spectre du phosphore dans les sels fondus et dans certains produits métallurgiques. (Read June 29.)	'C. R.' cxxii. 1534–1536; 'Chem. News,' lxxiv. 41 (Abs.); 'Nature,' liv. 239 (Abs.)
" .	Sur les spectres des métalloïdes dans les sels fondus. Soufre. (Read June 8.)	'C. R.' cxxii. 1326–1328; 'Beiblätter,' xx. 693 (Abs.)
W. N. Hartley .	Remarks on the Origin of some of the Lines and Bands observed in the Spectra from Swedish Bessemer Works. (Read June 20.)	'Proc. Roy. Soc.' lix. 98–101; 'Beiblätter,' xx. 367 (Abs.)
H. Kayser . .	The Spectra of Argon. (June) .	'Astrophys. J.' iv. 1–17.
H. Wilde . .	On the Spectral and other Properties of Thallium in Relation to the Genesis of the Elements. (June.)	'Chem. News,' lxxiii. 304–305; 'Beiblätter,' xxi. 633 (Abs.)
M. Bamberger .	Ueber den Nachweis von Argon in dem Gase einer Quelle in Perchtoldsdorf bei Wien. (Read July 9.)	'Monatsh. f. Chem.' xvii. 604–612.
G. Magnanini .	Intorno alla ipotesi della colorazione degli joni. (July.)	'Gazz. chim. ital.' xxvi. II. 92–96; 'Beiblätter,' xxi. 30–31 (Abs.)
W. Ramsay and J. N. Collie.	Sur l'homogénéité de l'argon et de l'hélium. (Read July 27.)	'C. R.' cxxiii. 214–216; 'Beiblätter,' xx. 823 (Abs.)
J. R. Rydberg .	Die neue Grundstoffe des Clèveitgases. (July.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 674–679; 'Nature,' liv. 455–456 (Abs.)
W. Spring . .	Sur la couleur et le spectre lumineux de quelques corps organiques. (July.)	'Bull. Acad. Belg.' [3], xxxii. 43–51; 'Beiblätter,' xxi. 31 (Abs.)
W. Wien . .	Ueber die Energievertheilung im Emissionsspectrum eines schwartzen Körpers. (July.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 662–669; 'Nature,' liv. 455 (Abs.)
H. Crew . .	Normal Spectrum of the Zinc Arc. (Aug.)	'Astrophys. J.' iv. 135–137.
J. R. Rydberg .	The New Elements of Clèveite Gas. (Aug.)	'Astrophys. J.' iv. 91–96; 'Chem. News,' lxxiv. 238–239.
P. Barrière . .	Lucium, a New Element. (Sept.) .	'Chem. News,' lxxiv. 159; 'Beiblätter,' xx. 930 (Abs.)
Birkeland . .	Sur un spectre des rayons cathodiques. (Read Sept. 28).	'C. R.' cxxiii. 492–495.
O. J. Lodge and B. Davies.	Extension of the Visible Spectrum. (Sept.)	'Nature,' liv. 622.
W. N. Hartley .	Argon and Helium. (Oct.) . .	'Chem. News,' lxxiv. 209; 'Beiblätter,' xxi. 632–633 (Abs.)
W. Crookes . .	The Alleged New Element, Lucium. (Nov.)	'Chem. News,' lxxiv. 259–260; 'Beiblätter,' xxi. 86 (Abs.)

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F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. V. (Read Nov. 19.)	'Sitzungsb. Akad. Wien,' cv. II.a, 989–1013; 'Wien. Anzeiger,' 1897, 7.
W. J. Humphreys.	A Further Study of the Effect of Pressure on the Wave-lengths of Lines in the Arc Spectra of Certain Elements. (Nov.)	'Astrophys. J.' iv. 249–262; 'Beiblätter,' xxi. 336–337 (Abs.)
O. J. Lodge and B. Davies.	Extension of the Visible Spectrum. (Nov.)	'Nature,' lv. 33.
O. Schott	Ueber electrische Capillarlicht. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], lix. 768–772; 'Nature,' lv. 214 (Abs.)
F. Schutzenberger and Boudouard.	Sur les terres du groupe yttrique contenues dans les sables monazités. (Read Nov. 16.)	'C. R.' cxxiii. 782–788; 'Nature,' lv. 95 (Abs.)
A. Swinton	Extension of the Visible Spectrum. (Nov.)	'Nature,' lv. 32–33.
W. N. Hartley and H. Ramage.	On the Occurrence of Gallium in the Clay-iron-stone of the Cleveland District of Yorkshire. Determination of Gallium in Blast-furnace Iron from Middlesbrough. (Read Dec. 17.)	'Proc. Roy. Soc.' lx. 393–407.
B. Hasselberg	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. III. Kobalt und Nickel. ('Handl. K. Svensk. Vet. Akad.' xxviii. No. 6, 44 pp.)	'Beiblätter,' xx. 692–693 (Abs.); 'Astrophys. J.' iv. 212–233, 288–304, 343–366, v. 38–49; 'Nature,' lv. 111 (Abs.)
A. Langlet	Prüfung von Kolm auf Helium (Oefvers. K. Vet. Acad. Stockholm,' liii. 663–664).	'Beiblätter,' xxi. 674 (Abs.)
J. R. Rydberg	Studien über das System der Spectren ('Verhandl. Ges. Deutsch. Naturf. u. Aerzte,' ii. I. Hälfte, 53).	'Beiblätter,' xx. [31], title.
V. Schumann	Von den brechbarsten Strahlen und ihrer photographischen Aufnahme. V.	'Jahrb. f. Photogr.' x. 42–45; 'Beiblätter,' xx. 975–976 (Abs.)

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M. Berthelot	Recherches sur l'hélium. (Read Jan. 18.)	'C. R.' cxxiv. 113–119; 'Nature,' lv. 311 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. VI. VII. VIII. IX. (Read Jan. 21, July 8.)	'Sitzungsb. Akad. Wien,' cvi. II.a, 36–53, 54–68, 337–356, 494–520.
A. de Gramont	Spectres des métalloïdes dans les sels fondus: silicium. (Read Jan. 25.)	'C. R.' cxxiv. 192–194; 'J. Chem. Soc.' lxxii. 238 (Abs.)
W. N. Hartley and H. Ramage.	On the Dissemination of some of the Rarer Elements, and the Mode of their Association in Common Ores and Minerals. (Read Jan. 21.)	'J. Chem. Soc.' lxxi. 533–547; 'Chem. News,' lxxix. 129–130 (Abs.)
H. Muraska and M. Kasuya.	Das Johanniskäferlicht und die Wirkung der Dämpfe von festen und flüssigen Körpern auf photographische Platten. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], lxiv. 186–192; 'Chem. Centr.' 1898. I. 697–698 (Abs.)

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J. Trowbridge and T. W. Richards.	The Spectra of Argon. (Jan.)	'Amer. J. Sci.' [4], iii. 15–20; 'Phil. Mag. [5], xliii. 77–83; 'Nature,' lv. 305 (Abs.)
J. S. Ames and W. J. Humphreys.	On the Spectra of Heavy and Light Helium. (Feb.)	'Astrophys. J.' v. 97–98; 'Beiblätter,' xxi. 514 (Abs.)
A. de Gramont	Spectres de dissociation des sels fondus; métalloïdes, chlore, brome, iode. (Feb.)	'Ann. Chim. et Phys.' [7], x. 214–234.
W. N. Hartley and H. Ramage.	On the Spectrographic Analysis of some Commercial Samples of Metals, of Chemical Preparations, and of Minerals from the Stassfurt Potash Beds. (Read Feb. 18.)	'J. Chem. Soc.' lxxi. 547–550; 'Chem. News,' lxxv. 151 (Abs.); 'Chem. Centr.' 1897, I. 665 (Abs.)
O. Lohse	Untersuchungen des violetten Theiles einiger linienreichen Metallspectra. (Read Feb. 18.)	'Sitzungsb. Akad. Berl.' 1897, 179–197.
W. Ramsay and M. W. Travers.	The Gaseous Constituents of Certain Mineral Substances and Natural Waters. (Read Feb. 4.)	'Proc. Roy. Soc.' lx. 442–448; 'Beiblätter,' xxi. 300 (Abs.)
W. A. Tilden	On the Gases Enclosed in Crystalline Rocks and Minerals. (Read Feb. 4.)	'Proc. Roy. Soc.' lx. 453–457; 'Nature,' lv. 381–382 (Abs.); 'Chem. News,' lxxv. 169–170.
M. W. Travers	Some Experiments on Helium. (Read Feb. 4.)	'Proc. Roy. Soc.' lx. 449–453; 'Beiblätter,' xxi. 300 (Abs.)
J. Trowbridge and T. W. Richards.	The Multiple Spectra of Gases. (Feb.)	'Amer. J. Sci.' [4], iii. 117–120; 'Nature,' lv. 406 (Abs.); 'Phil. Mag.' [5], xliii. 135–139.
W. N. Hartley	Experiments on the Flame Spectrum of Carbon Monoxide. (Read March 18.)	'Proc. Roy. Soc.' lxi. 217–219; 'Beiblätter,' xxi. 735 (Abs.)
G. Urbain and E. Budischovsky.	Recherches sur les sables monazités. (Read March 22.)	'C. R.' cxxiv. 618–621; 'Chem. News,' lxxv. 181–182.
H. Kayser	On the Spectrum of Hydrogen. (April.)	'Astrophys. J.' v. 243; 'Beiblätter,' xxi. 734 (Abs.)
H. Becquerel	Explication de quelques expériences de M. G. Le Bon. (Read May 10.)	'C. R.' cxxiv. 984–988; 'Chem. News,' lxxv. 280–281.
W. N. Hartley and H. Ramage.	A Spectrographic Analysis of Iron Meteorites, Siderolites, and Meteoric Stones. (Read May 19.) ('Proc. Roy. Soc. Dublin' [N.S.], viii. Part 6.)	'Nature,' lvii. 546 (Abs.); 'Chem. News,' lxxvii. 121–122.
G. Le Bon	Sur les propriétés de certaines radiations du spectre. (Read May 24.)	'C. R.' cxxiv 1148–1151.

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J. S. Ames and W. J. Humphreys.	Note on the Effect of Pressure upon the Series in the Spectrum of an Element. (June.)	'Johns Hopkins Univ. Circ.' xvi. 41–42 ; 'Phil. Mag.' [5], xliv. 119–122 ; 'Chem. News,' lxxvi. 21–22 ; 'Beiblätter,' xxi. 974–975 (Abs.); 'Chem. Centr.' 1897, II. 324 (Abs.)
W. Arnold . .	Ueber Luminescenz. (June) .	'Ann. Phys. u. Chem.' [N.F.], lxi. 313–329.
W. Huggins and Mrs. Huggins.	On the Relative Behaviour of the H and K Lines of the Spectrum of Calcium. (Read June 17).	'Proc. Roy. Soc.' lxi. 433–441 ; 'Beiblätter,' xxi. 735–736 (Abs.); 'Nature,' lvi. 262 (Abs.)
W. J. Humphreys .	Changes produced by Pressure in the Wave Frequencies of the Lines of Emission Spectra of Elements. (June.)	'Johns Hopkins Univ. Circ.' xvi. 43–44 ; 'Beiblätter,' xxii. 219–221 (Abs.)
P. E. Lecoq de Boisbaudran.	Examen de quelques spectres. (Read June 8.)	'C. R.' cxxiv. 1288–1290.
„ „ .	Examen de quelques spectres. (Read June 21.)	'C. R.' cxxiv. 1419–1421.
J. N. Lockyer .	On the Unknown Lines observed in the Spectra of Certain Minerals. (Read June 4.)	'Proc. Roy. Soc.' lx. 133–140 ; 'J. Chem. Soc.' lxxii. II. 293 (Abs.); 'Nature,' liv. 261–263 (Abs.)
„ . .	Further Observations of Enhanced Lines. (Read June 17.)	'Proc. Roy. Soc.' lxi. 441–444 ; Beiblätter,' xxi. 975 (Abs.)
C. E. Mendenhall and F. A. Saunders.	Preliminary Note on the Energy Spectrum of a Black Body. (June.)	'Johns Hopkins Univ. Circ.' xvi. 47 ; 'Phil. Mag.' [5], xliv. 136.
A. de Gramont .	Observations sur les spectres des composés. (Read July 23.)	'Bull. Soc. Chim.' [3], xvii. 774–778 ; 'Chem. Centr.' 1897, II. 787–788 (Abs.)
„ .	Spectres de dissociation des sels fondus. Métaux alcalins, sodium, lithium, potassium. (Read July 23.)	'Bull. Soc. Chim.' [3], xvii. 778–782; 'Chem. Centr.' 1897, II. 785 (Abs.)
„ .	Sur le spectre du carbone. (Read July 19.)	'C. R.' cxxv. 172–175; 'J. Chem. Soc.' lxxii. II. 533–534 (Abs.)
„ .	Sur le spectre des lignes du carbone dans les sels fondus. (Read July 26.)	'C. R.' cxxv. 238–240 ; 'J. Chem. Soc.' lxxii II. 533–534 (Abs.); 'Beiblätter,' xxi. 973–974 (Abs.)
W. N. Hartley .	On the Spectrum of Cyanogen as produced and modified by Spark Discharges. (Recd. July 13.)	'Proc. Roy. Soc.' lx. 216–221 ; 'J. Chem. Soc.' lxxii. II. 293–299 (Abs.) ; 'Beiblätter,' xxi. 734–735 (Abs.)

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C. Runge and F. Paschen.	Ueber die Serienspectra der Elemente Sauerstoff, Schwefel und Selen. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxi. 641–686; 'Chem. Centr.' 1898, I. 298–299 (Abs.); 'Nature,' lvi. 388 (Abs.); 'Science Abstr.' i. 10 (Abs.); 'J. Chem. Soc.' lxxii. II. 533 (Abs.)
P. Zeeman . .	Doublets and Triplets in the Spectrum produced by External Magnetic Forces. (July.)	'Phil. Mag.' [5], xliv. 55–60.
W. J. Humphreys .	Changes in the Wave Frequencies of the Lines of Emission Spectra of Elements. (Aug.)	'Brit. Assoc. Report,' 1897, 556–557.
A. C. Jones . .	Ueber einige Emissionsspectra des Cadmiums, Zinks und der Haloidverbindungen des Quecksilbers und einiger anderen Metalle. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], lxii. 30–53; 'J. Chem. Soc.' lxxii. II. 534 (Abs.); 'Science Abstr.' i. 10 (Abs.)
C. Runge and F. Paschen.	On the Spectra of Oxygen, Sulphur, and Selenium. (Aug.)	'Brit. Assoc. Report,' 1897, 555 (Abs.)
G. A. Hemsalech .	On some New Lines in the Spark Spectrum of Aluminium. (Sept.)	'Phil. Mag.' [5], xliv. 289–291; 'J. Chem. Soc.' lxxii. II. 534 (Abs.); 'Beiblätter,' xxi. 975 (Abs.)
W. J. Humphreys .	Changes in the Wave Frequencies of the Lines of Emission Spectra of Elements; their dependence upon the elements themselves and upon the physical conditions under which they are produced. (Oct.)	'Astrophys. J.' vi. 169–232.
J. R. Rydberg .	The New Series in the Spectrum of Hydrogen. (Oct.)	'Astrophys J.' vi. 233–238.
" .	On Triplets with Constant Differences in the Line Spectrum of Copper. (Oct.)	'Astrophys. J.' vi. 239–243; 'Beiblätter,' xxii. 153–154 (Abs.)
H. Wilde . .	Sur quelques nouvelles lignes spectrales de l'oxygène et du thallium. (Read Nov. 8.)	'C. R.' cxxv. 705–709; 'Beiblätter,' xxii. 219 (Abs.); 'J. Chem. Soc.' lxxix. II. 105 (Abs.)
A. de Gramont .	Spectres de dissociation des sels fondus; soufre. (Read Dec. 27.)	'Bull. Soc. Chim.' [3], xix. 54–57; 'Chem. Centr.' 1898, I. 550 (Abs.)
" .	Spectres de dissociation des sels fondus; phosphore. (Read Dec. 27.)	'Bull. Soc. Chim.' [3], xix. 57–58; 'Chem. Centr.' 1898, I. 549–550 (Abs.)
" .	Spectres de dissociation des composés phosphoreux solides. (Read Dec. 27.)	'Bull. Soc. Chim.' [3], xix. 58–59; 'Chem. News,' lxvii. 88–90.
R. Nasini, F. Anderlini, and R. Salvadori.	Gas delle terme di Abano dei soffioni boraciferi della Toscana, e gas combustibili dell' Apparino Bolognese. (Read Dec 17.)	'Gazz. chim. ital.' xxviii. I. 81–153; 'Chem. Centr.' 1898, I. 917 (Abs.)

Z. P. Bouman	Emission und Absorption von Quarz und Glas bei verschiedenen Temperaturen. (Inaug. Dissert. Amsterdam, 1897, 91 pp.)	'Zittingsverl. Akad. Amsterdam,' 1896–7, 438–442; 'Beiblätter,' xxi. 589 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. X. ('Wien. Anz.' 1897, 254.)	'Beiblätter,' xxii. [17] (title).
A. L. Foley	Arc Spectra ('Phys. Review,' v. 129–152).	'Beiblätter,' xxii. 152 (Abs.)
B. Hasselberg	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. IV. Das Spectrum des Mangans. ('Handl. Svensk. Vet. Akad.' xxx. No. 8, 20 pp.)	'Beiblätter,' xxii. [57] (title).
H. Kayser	Ueber die Bogenspectra der Elemente der Platingruppe ('Abhandl. Akad. Berlin,' 1897).	'Beiblätter,' xxii. [44] (title).
H. Konen	Ueber die Spectren des Iod. (Inaug. Dissert. Bonn, 72 pp.)	'Beiblätter,' xxii. [11] (title).
G. B. Rizzo	Argon ('Atti Accad. Torino,' xxxii. 50 pp.)	'Beiblätter,' xxi. [115] (title).
Widmark	Im gränzen för det synliga spektrum ('Oefvers. K. Vet. Akad. Stockholm,' liv. 287–309).	'Beiblätter,' xxi. [111] (title).
E. Wiedemann	Ueber Spectralerscheinungen ('Verhandl. Ges. Deutsch. Naturf. u. Aerzte,' II. 1. Hälfte, 66).	'Beiblätter,' xxi. [85] (title).

III.

ABSORPTION SPECTRA.

1886.

A. Maschek	Ueber eine spectroscopische Methode zum Nachweis des Blutfarbenstoffes ('Pharm. Centralhalle,' xxvii. 317–320, 326–330, 340–343).	'Ber.' xix. (Ref.), 584 (Abs.)

1888.

C. H. Wolff	Ueber den spectroscopischen Nachweis minimaler Blutmengen im Harn, sowie in anderen Flüssigkeiten ('Pharm. Centralhalle,' viii. 637–639).	'Ber.' xxi. (Ref.), 315 (Abs.)

1889.

A. Hasterlik	Kritische Studien über die bisherigen Methoden zum Nachweis fremder Farbstoffe im Weine. (Inaug. Dissert. Erlangen, 1889.)	'Beiblätter,' xiv. 281 (title).

B. Hasselberg	Untersuchungen über das Absorptionspectrum des Broms. (Read Oct. 8.)	'Handl. K. Svensk. Vet. Akad.' xxiv. No. 3, 53 pp.
N. A. Monteverde	Sur la chlorophylle	'Ann. Agronom.' xviii. 268–270; 'J. Chem. Soc.' lxii. 1155–1156 (Abs.)

1891.

P. Dittrich	Ueber methämoglobinbildende Gifte. (Oct.)	'Arch. f. exper. Pathol. u. Pharmakol.' xxix. 247–281; 'Ber.' xxv. (Ref.), 913 (Abs.)

1892.

H. Bertin-Sans and J. Moitessier.	Sur la formation de l'oxyhémoglobine au moyen de l'hématine et d'une matière albuminoïde. (Read April 11.)	'C. R.' cxiv. 923–926; 'J. Chem. Soc.' lxii. 1017 (Abs.)
A. H. Church	Researches on Turacin, an animal pigment containing copper. (Read April 28.)	'Phil. Trans.' clxxxiii. A. 511–530.
K. Olszewski and A. Witkowski.	Propriétés optiques de l'oxygène liquide. (May.)	'Bull. internat. de l'Acad. Sci. de Cracovie,' 1892, 340–343; 'Naturw. Rundschau,' viii. 75 (Abs.); 'Chem. Centralbl.' 1893, I. 595 (Abs.); 'J. Chem. Soc.' lxiv. II. 353 (Abs.)
A. Brun	Note sur le spectre d'absorption des grenats almandines. (Read July 7.)	'Arch. de Genève' [3], xxviii. 410–412; 'Zeitschr. f. Kryst. u. Min.' xxiv. 621 (Abs.); 'Beiblätter,' xx. 31–32 (Abs.)
S. Forsling	Om Absorptionspectra hos Didym och Samarium i det ultravioletta spektret. (Read Nov. 9.)	'Bihang till K. Svensk. Vet. Akad. Handl.' xviii. I. No. 10, 32 pp.; 'Beiblätter,' xviii. 562 (Abs.)
A. Görtz	Ueber spectrometrische Affinitätsbestimmungen. (Diss. Tübingen, 1892, 574 pp.)	'Beiblätter,' xvii. [16] (title).
H. Graebe	Unterschungen des Blutfarbstoffes auf sein Absorptionsvermögen für violette und ultraviolette Strahlen. (Inaug. Dissert. Dorpat, 1892.)	'Zeitschr. f. anal. Chem.' xxxiii. 771–772; 'Chem. News,' lxxii. 9–11; 'Beiblätter,' xx. 127 (Abs.)

1893.

W. Ackroyd	On the Origin of Colour. Iodine and Iodine Solutions. (Read Feb. 10.)	'Chem. News,' lxvii. 27, 64–65, 111–112.
G. Magnanini	Intorno alla ipotesi della colorazione degli joni. (Read April 9.)	'Rend. R. Acad. d. Lincei' [5], ii. I. sem. 369–376; 'Zeitschr. f. physikal. Chem.' xii. 56–62; 'J. Chem. Soc.' lxiv. II. 510 (Abs.)

ABSORPTION SPECTRA, 1893, 1894.

G. Magnanini and T. Bentivoglio.	Intorno allo spettro di assorbimento delle soluzioni di alcuni cromo-ossalati della serie bleu. (Read July 2.)	'Rend. R. Accad. d. Lincei' [5], ii. II. sem. 17–23 ; 'Gazz. chim. ital.' xxiii. II. 444–451 ; 'Ber.' xxvi. (Ref.), 926–927 (Abs.) ; 'Beiblätter,' xvii. 926 (Abs.) ; 'J. Chem. Soc.' lxvi. II. 129 (Abs.) ; 'Chem. News,' lxix. 157 (Abs.)
V. Schumann	Das Absorptionsspectrum des Bromsilbers bei steigender Temperatur.	'Jahrb. f. Photogr.' vii. (1893), 160–165 ; 'Beiblätter,' xvii. 1060–1061 (Abs.)
G. Krüss and E. Thiele.	Ueber die Lösungzustand des Iod, und die wahrscheinliche Ursache der Farbenunterschiede seiner Lösungen. (Jan).	'Zeitschr. f. anorg. Chem.' vii. 52–81 ; 'J. Chem. Soc.' lxvi. II. 445–446 (Abs.)

1894.

G. B. Rizzo	Sulle proprietà delle linee e delle bande negli spettri d'assorbimento. (Jan.)	'Il Nuovo Cimento,' xxxv. 132–136 ; 'Beiblätter,' xviii. 836–837 (Abs.)
G. Hüfner	Neue Versuche zur Bestimmung der Sauerstoffcapacität Blutfarbstoffs. (Feb.)	'Arch. f. Anat. u. Physiol. 1894, Physiol. Abth. 130–176.
E. Schunck and L. Marchlewski.	Zur Chemie der Chlorophyll. (March.)	'Am. Chem. u. Pharm.' cclxxviii. 329–345 ; 'J. Chem. Soc.' lxvi. I. 341–342 (Abs.)
A. E. Garrod	A Contribution to the Study of the Yellow Colouring Matter of the Urine. (Received Feb. 5. Read April 26.)	'Proc. Roy. Soc.' lv. 394–407.
J. M. Eder and E. Valenta.	Absorptionsspectren von farblosen und gefärbten Gläsern, mit besonderen Berücksichtigung des Ultraviolett. (Read May 4.)	'Denkschr. Akad. Wien,' 1894, 285–295 ; 'Beiblätter,' xix. 61–64 (Abs.)
J. Janssen	Sur les spectres de l'oxygène aux hautes températures. (Read May 7.)	'C. R.' cxviii. 1007–1009 ; 'J. Chem. Soc.' lxvi. II. 337 (Abs.) ; 'Ber.' xxvii. (Ref.), 278–279 (Abs.) ; 'Beiblätter,' xviii. 837–838 (Abs.)
P. Sabatier	Spectres d'absorption du bromure cuivrique. (Read May 7.)	'C. R.' cxviii. 1042–1045 ; 'Ber.' xxvii. (Ref.), 489–490 (Abs.) ; 'Beiblätter,' xviii. 838 (Abs.) ; 'J. Chem. Soc.' lxvi. II. 304 (Abs.) ; 'Chem. News,' lxix. 257–258 (Abs.) ; 'Nature,' l. 72 (Abs.)

ABSORPTION SPECTRA, 1894, 1895.

P. Sabatier . .	Spectres d'absorption des solutions bromhydriques de bromure cuivrique. (Read May 21.)	'C. R.' cxviii. 1144–1146; 'Chem. News,' lxix. 275 (Abs.); 'Ber.' xxvii. (Ref.), 490 (Abs.); 'Beiblätter,' xviii. 1048 (Abs.); 'J. Chem. Soc.' lxvi. II. 373 (Abs.)
H. Becquerel and C. Brongniart.	La matière verte chez les Phyllies, orthoptères de la famille des Phasmides. (Read June 11.)	'C. R.' cxviii. 1299–1303; 'Chem. News,' lxix. 312 (Abs.); 'Ber.' xxvii. (Ref.), 517 (Abs.)
T. Ewan . .	On the Absorption Spectra of Dilute Solutions. (Read June 21.)	'Proc. Roy. Soc.' li. 117–161.
Mecke and Wimmer	Nachweise von Blutflecken. (Nov.)	'Zeitschr. f. anal. Chem.' xxxiv. 129–131; 'Chem. News,' lxxi. 238.
A. E. Garrod . .	Hæmatoporphyrin in Normal Urine.	'J. Physiol.' xvii. 349–352; 'J. Chem. Soc.' lxviii. II. 55 (Abs.)
C. Haacke . .	Spectrophotometrische Untersuchungen über die Einwirkung von Salzsäure auf einige Substitutionsproducte des Fuchsins. (Diss. Tübingen, 1894, 49 pp.)	'Beiblätter,' xx. 64 (title).
N. A. Monteverde .	De la protochlorophylle ('Bot. Centralblatt,' lix. 284).	'Ann. Agronom.' xxi. 90 (Abs.); 'J. Chem. Soc.' lxviii. I. 429–430 (Abs.)
E. Schöne .	Absorption Spectrum of Ozone (Russ. Nat. and Phys. Congress, Moscow, 1894, No. 10.)	'Chem. News,' lxix. 289 (Abs.)

1895.

E. Thiele . .	Spectrophotometrische Untersuchungen der verschiedenfarbigen Iodlösungen. (Jan.)	'Zeitschr. f. physikal. Chem.' xvi. 147–155; 'Beiblätter,' xix. 426–427 (Abs.); 'Proc. Phys. Soc.' xiii. 113–114 (Abs.); 'Ber.' xxviii. (Ref.), 720 (Abs.); 'J. Chem. Soc.' lxviii. II. 193–194 (Abs.)
A. Étard .	Pluralité des chlorophylles. Deuxième chlorophylle isolée dans la luzerne. (Read Feb. 11.)	'C. R.' cxx. 328–331; 'J. Chem. Soc.' lxviii. I. 389 (Abs.)
E. Schunck . .	Contributions to the Chemistry of Chlorophyll. (Read Feb. 14.)	'Proc. Roy. Soc.' lvii. 314–322.
A. Étard . .	Sur l'origine moléculaire des bandes d'absorption des sels de cobalt et de chrome. (Read May 13.)	'C. R.' cxx. 1057–1060; 'Ber.' xxviii. (Ref.), 592 (Abs.); 'Beiblätter,' xix. 568 (Abs.); 'Proc. Phys. Soc.' xiii. 310–311 (Abs.); 'Chem. News,' lxxi. 269 (Abs.); 'Nature,' lii. 96 (Abs.); 'J. Chem. Soc.' lxx. II. 133 (Abs.)

Absorption Spectra, 1895.

E. Merritt . .	On the Absorption of Certain Crystals in the Infra-red, as dependent on the Plane of Polarisation. (May.)	'Phys. Review,' ii. 424–441; 'Beiblätter,' xix. 694–695 (Abs.); 'Proc. Phys. Soc.' xiii. 310 (Abs.)
T. Ewan . .	On the Absorption Spectra of Dilute Solutions. (Read June 21.)	'Proc. Roy. Soc.' lvi. 286–287, lvii. 117–161; 'Ber.' xxviii. (Ref.), 411 (Abs.); 'Beiblätter,' xviii. 998–999, xix. 888 (Abs.); 'J. Chem. Soc.' lxviii. II. 433–434 (Abs.); 'Nature,' l. 491 (Abs.)
J. Janssen . .	Note sur la loi d'absorption des bandes du spectre de l'oxygène. (Read June 17.)	'C. R.' cxx. 1306–1310; 'Proc. Phys. Soc.' xiii. 341–342 (Abs.); 'Nature,' lii. 303–304 (Abs.); 'Beiblätter,' xx. 534 (Abs.)
E. Aschkinass .	Ueber das Absorptionspectrum des flüssigen Wassers und über die Durchlässigkeit des Augenmedium für rothe und ultrarothe Strahlen. (July.)	'Ann. Phys. u. Chem.' [N.F.], lv. 401–422; 'Nature,' lii. 382 (Abs.); 'Proc. Phys. Soc.' xiii. 436 (Abs.)
G. D. Liveing and J. Dewar.	Sur le spectre d'absorption de l'air liquide. (Read July 15.)	'C. R.' cxxi. 161–164; 'Beiblätter,' xx. 31 (Abs.); 'Proc. Phys. Soc.' xiii. 403 (Abs.); 'Chem. News,' lxxii. 65 (Abs.); 'Nature,' lii. 312 (Abs.); 'Ber.' xxix. (Ref.), 63 (Abs.)
J. Pauer . .	Ueber die Absorptionsspectra einiger Verbindungen im dampförmigen und flüssigen Zustand. (Read July 7.)	'Sitzungsb. phys. med. Soc. Erlangen,' xxvii. 120–126; 'Beiblätter,' xx. 696 (Abs.); 'Chem. Centr. 1896,' I. 1122 (Abs.); 'J. Chem. Soc.' lxxii. II. 393 (Abs.)
F. Hamburger .	Ueber Farbenwechsel verdünnter Lösungen von chromoxalsaurem Kali. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], lvi. 173–174; 'J. Chem. Soc.' lxx. II. 86 (Abs.)
G. Magnanini .	Intorno allo spettro di absorbimento di alcuni cromosolfocianati. (Read Aug. 11.)	'Gazz. chim. ital.' xxv. II. 373–379; 'Beiblätter,' xx. 695–696 (Abs.); 'Ber.' xxix. (Ref.), 269 (Abs.); 'J. Chem. Soc.' lxx. II. 345 (Abs.)
G. H. Bailey . .	The Spectrum of the Haloid Salts of Didymium. (Sept.)	'Brit. Assoc. Rep.' 1895, 773; 'Beiblätter,' xx. 31 (Abs.)
G. Krüss and H. Krüss.	Eine neue Methode der quantitativen Spectralanalyse. (Sept.)	'Zeitschr. f. anorg. Chem.' x. 31–43; 'Beiblätter,' xx. 26 (Abs.); 'Proc. Phys. Soc.' xiv. 14 (Abs.); 'J. Chem. Soc.' lxx. II. 215 (Abs.); 'Ber.' xxix. (Ref.), 147–148 (Abs.)

ABSORPTION SPECTRA, 1895, 1896.

G. D. Liveing and J. Dewar.	On the Refraction and Dispersion of Liquid Oxygen, and the Absorption Spectrum of Liquid Air. (Sept.)	'Phil. Mag.' [5], xl. 268–272; 'J. Chem. Soc.' lxviii. II. 471 (Abs.); 'Chem. News,' lxxii. 154; 'Ber.' xxix. (Ref.), 110 (Abs.)
R. Möhlau and K. Uhlmann.	Zur Kenntniss der Chinazin- und Oxazinfarbstoffe. (Oct.)	'Ann. Chem. u. Pharm.' cclxxxix. 128–130; 'J. Chem. Soc.' lxx. I. 166–169 (Abs.)
B. Paulowski	Ueber Allofluorescein. (Read Oct. 14.)	'Ber.' xxviii. 2360–2362.
E. Schunck and L. Marchlewski.	Zur Chemie des Chlorophylls. (Oct.)	'Ann. Chem. u. Pharm.' cclxxxix. 81–107; 'J. Chem. Soc.' lxviii. I. 296–297 (Abs.)
Lecoq de Boisbaudran.	Sur un élément, probablement nouveau, existant dans les terbines. (Read Nov. 18.)	'C. R.' cxxi. 709; 'Beiblätter,' xx. 276 (Abs.); 'Nature,' liii. 96 (Abs.)
G. Krüss	Beziehungen zwischen Zusammensetzung und Absorptionsspectrum organischen Verbindungen. Nachtrag. (Dec.)	'Zeitschr. f. physikal. Chem.' xviii. 559–562; 'Beiblätter,' xx. 197 (Abs.); 'J. Chem. Soc.' lxx. II. 285 (Abs.)
A. E. Garrod	A Contribution to the Study of Uroerythrin.	'J. Physiol.' xvii. 439–450; 'J. Chem. Soc.' lxviii. I. 315–316 (Abs.)
J. Georgenburger	Hæmoglobin and its Derivatives ('Pharm. Zeitschr. Russ.' xxxiv. 102–104).	'Chem. Centr.' 1895, I. 701–702; 'J. Chem. Soc.' lxx. II. 485 (Abs.)
H. C. Poinsen	Ang-Khak, Chines Pilzfarbstoff zum Färben der Esswaaren.	'Chemiker Zeitung,' xix. II. 1311; 'Chem. News,' lxxii. 105.
O. Postma	Einiges über Ausstrahlung und Absorption. (Inaug.-Diss. Amsterdam, 1895, 94 pp.)	'Beiblätter,' xxii. 98 (Abs.)

1896.

P. H. Bayrac and C. Camichel.	Sur l'absorption de la lumière par des dissolutions d'indophénole. (Read Jan. 27.)	'C. R.' cxxii. 193–195; 'Ber.' xxix. (Ref.), 166 (Abs.); 'J. Chem. Soc.' lxx. II. 345–346 (Abs.); 'Chem. News,' lxxiii. 95 (Abs.); 'Nature,' liii. 335 (Abs.); 'Beiblätter,' xxi. 740 (Abs.)
L. Marchlewski	Die Chemie des Chlorophylls. (Hamburg, 82 pp.) (Jan.)	'Chem. News,' lxxiii. 23 (Review).
E. Schunck and L. Marchlewski.	Contributions to the Chemistry of Chlorophyll; Phylloporphyrin and Hæmatoporphyrin: a comparison. (Read Jan. 30.)	'Proc. Roy. Soc.' lix. 233–239.

ABSORPTION SPECTRA, 1896.

A. Gamgee	On the Absorption of the Extreme Violet and Ultra-violet Rays of the Solar Spectrum by Hæmoglobin, its Compounds, and Certain of its Derivatives. (Read Feb. 13.)	'Proc. Roy. Soc.' lix. 276–279; 'Arch. de Genève' [3], xxxiv. 585–588; 'Beiblätter,' xx. 650, 696–697 (Abs.); 'Nature,' liii. 478–479 (Abs.)
A. Tschirch	Der Quarzspectrograph und einige damit vorgenommene Untersuchungen von Pflanzenfarbstoffe. (Read Feb. 28.)	'Ber. deutsch. bot. Gesellsch.' xiv. 76–94; 'Naturw. Rundschau,' xi. 240–241 (Abs.); 'Beiblätter,' xx. 535–536 (Abs.)
A. Gamgee	On the Relation of Turacin and Turacoporphyrin to the Colouring Matter of the Blood. (Read Mar. 19.)	'Proc. Roy. Soc.' lix. 339–342; 'Nature,' liii. 574–575.
W. Spring	Sur la couleur des alcoöls comparée à la couleur de l'eau. (Read March 7.)	'Bull. Acad. Belg.' [3], xxxi. 246–256; 'Beiblätter,' xx. 535 (Abs.)
B. Tollens	Ueber den Nachweis der Pentosen mittels der Phloroglucinsalzsäureabsatzmethode. (Read April 18.)	'Ber.' xxix. 1202–1209.
E. Schunck and L. Marchlewski.	Zur Chemie des Chlorophylls. (Read May 11.)	'Ber.' xxix. 1347–1352.
A. Tschirch	Zur Chemie des Chlorophylls. (Read June 22.)	'Ber.' xxix. 1766–1770.
B. Donath	Bolometrische Untersuchungen über Absorptionsspectra fluorescirender Substanzen und ätherischer Oele. (July.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 609–661; 'Nature,' liv. 455 (Abs.)
V. Agafonoff	Sur l'absorption du spectre ultra-violet par les corps cristallisés. (Read Sept. 28.)	'C. R.' cxxiii. 490–492; 'Chem. News,' lxxiv. 204–205; 'Arch. de Genève [4], ii. 249–264; 'Beiblätter,' xxi. 227–228 (Abs.)
A. Étard	Les spectres des chlorophylles. (Read Nov. 16.)	'C. R.' cxxiii. 824–828; 'Beiblätter,' xxi. 32 (Abs.)
G. Eberhard	Die Schirmwirkung der Farbensensibilisatoren. ('Photographische Rundschau,' x. 42–46, 76–80).	'Beiblätter,' xx. 982 (Abs.)
J. M. Eder	Die Wirkung von Farbensensibilisatoren bei orthochromatischen Platten.	'Jahrb. f. Photog.' x. 166–167; 'Beiblätter,' xx. 981–982 (Abs.)
A. von Hübl	Die Schirmwirkung der Farbensensibilisatoren.	'Jahrb. f. Photog.' x. 289–293; 'Beiblätter,' xx. 982 (Abs.)
A. Lumière and L. Lumière.	Ueber der Orthochromatismus	'Jahrb. f. Photog.' x. 146–151; 'Beiblätter,' xx. 983 (Abs.)
E. Schunck and L. Marchlewski.	Zur Chemie des Chlorophylls. (IV. Abhandlung.)	'Ann. Chem. u. Pharm.' ccxc. 306–313; 'Ber.' xxix. (Ref.), 415 (Abs.)

ABSORPTION SPECTRA, 1896, 1897.

M. Ransohoff . .	Ueber die Verteilung des Absorptionsvermögens einiger einfacherer Kohlenstoffverbindungen im ultraroten Gebiete des Spektrums. (Inaug. Dissert. Berlin, 1896, 32 pp.)	'Beiblätter,' xxi. 737–740 (Abs.)
A. Tschirch . .	Untersuchungen reiner Blattfarbstoffe mit dem Quartzspectrographen: Beziehungen des Chlorophylls zum Blut.	'Phot. Mittheil.' xxxii. 397–399.
O. Wallach . .	Ueber das Absorptionsvermögen gewisser ungesättiger Ketone für die violetten Lichtstrahlen. ('Göttingen. Nachr.' 1896, Heft 4, 1–5).	'Chem. Centr.' 1897, i. 372–374; 'Beiblätter,' xxi. 633–634 (Abs.); 'J. Chem. Soc.' lxxiv. I. 194 (Abs.)
E. Wiedemann and G. C. Schmidt.	Fluorescenz und Verbindungsspectra organischer Dämpfe.	'Jahrb. f. Photog.' x. 14–15.
A. Wroblewsky .	Anwendung des Glan'schen Spectrophotometers auf die Tierchemie. I. Quantitative Bestimmung des Hämoglobins im Blute. II. Quantitative Bestimmung der Rhodansalze im Speichel ('Anz. Akad. Krakau,' 1896, pp. 306–309, 386–390).	'Chem. Centr.' 1897, ii. 532 (Abs.); 'Beiblätter,' xxi. 573 (Abs.)

1897.

O. Lohse . .	Untersuchung des violetten Theils einiger linienreicher Metallspectra. (Read Feb. 18.)	'Sitzungsb. Berl. Akad.' 1897, 179–197; 'Nature,' lvi. 62–63 (Abs.)
H. Rubens and A. Trowbridge.	Beitrag zur Kenntniss der Dispersion und Absorption der ultrarothen Strahlen in Steinsalz und Sylvin. (March.)	'Ann. Phys. u. Chem.' [N.F.], lx. 724–739.
C. Watson . .	The Additional Colouring Matters of *Fucus vesiculosus*. (March.)	'Nature,' lv. 508.
A. Étard . .	Dédoublement de la bande fondamentale des chlorophylles. (Read June 14.)	'C. R.' cxxiv. 1351–1354; 'Nature,' lvi. 191 (Abs.); 'Beiblätter,' xxi. 740–741 (Abs.); 'Chem. Centr.' 1897, II. 207 (Abs.); 'J. Chem. Soc.' lxxii. I. 575–579 (Abs.)
L. Lewin . .	Die spectroscopische Blutuntersuchung. (June.)	'Arch. der Pharm.' ccxxxv. 245–255; 'Chem. Centr.' 1887, II. 381 (Abs.); 'J. Chem. Soc.' lxxii. II. 534 (Abs.)
J. Pauer. . .	Absorption ultravioletter Strahlen durch Dämpfe und Flüssigkeiten. (June.)	'Ann. Phys. u. Chem.' [N.F.], lxi. 363–379.
J. Königsberger .	Ueber die Absorption von ultrarothen Strahlen in doppelbrechenden Krystallen. (July.	'Ann. Phys. u. Chem.' [N.F.], lxi. 687–704.

G. Dimmer . .	Ueber die Absorptionsspectren von Didymsulphat und Neodidymammonnitrat ('Wien. Anz.' 1879, 254).	'Beiblätter,' xxii. [17] (title.)
Z. Donogány . .	Die Darstellung des Hämochromogens als Blutreaction, mit besonderer Berücksichtigung des Nachweises von Blut im Harn.	'Arch. f. Anat. u. Physiol.' cxlviii. 234–243; 'J. Chem. Soc.' lxxii. II. 468 (Abs.)
H. Haertes . .	Differentialdiagnose zwischen Kohlendunst- und Leuchtgasvergiftung. (Inaug. Dissert. Berlin.)	'Chem. Centr.' 1897, II. 529 (Abs.)
J. Königsberger .	Ueber die Absorption von ultraroten und ultravioletten Strahlen in doppelbrechenden Krystallen. (Inaug. Dissert. Berlin, 1897, 33 pp.)	'Beiblätter,' xxi. 414–416 (Abs.)
J. Stscheglajew .	Dispersion anomale dans les solutions de fuchsine.	'J. Russ. Phys. Chem. Soc.' xxviii. II. 41–55; 'Beiblätter,' xxi. 409 (Abs.)
W. Spring . .	Sur les spectres d'absorption de quelques corps organiques incolorés, et ses relations avec la structure moléculaire. ('Arch. de Genève' [4], iii. 437–463.)	'Bull. Acad. Roy. de Belg.' [3], xxxiii. 165–195; 'Rec. des Trav. Chim. des Pays-Bas' [2], xvi. 1–25; 'Chem. Centr.' 1897, I. 1114–1115, II. 8–9 (Abs.); 'J. Chem. Soc.' lxxiv. II. 201 (Abs.); 'Beiblätter,' xxi. 975–976 (Abs.)

IV.

PHYSICAL RELATIONS.

1884.

H. Merczyng . .	Sur les propriétés focales des réseaux. (In Russian.)	'Sitzungsb. d. Krakauer Akad.' ix. 257–279; 'J. Soc. Phys.-Chim. Russe,' xv. 92–102; 'Beiblätter,' viii. 121–122 (Abs.)

1887.

H. F. Weber . .	Die Entwickelung der Lichtemission glühender fester Körper. (Read June 9.)	'Sitzungsb. Akad. Berl.' 1887, 491–504; 'Beiblätter,' xvii. 1052–1054 (Abs.)

1888.

W. C. Röntgen .	Ueber den Einfluss des Druckes auf die Brechungsexponenten von Schwefelkohlenstoff und Wasser ('Ber. oberh. Ges. f. Natur- und Heilkunde,' Giessen, 1888, xxvi. 58–60).	

1889.

G. Mengarini . .	Ueber das Maximum der Lichtstärke im Sonnenspectrum. (June.)	'Untersuchungen zur Naturlehre der Menschen und der Thiere,' xiv. 119–137; 'Nature,' xli. 374 (Abs.); 'Beiblätter,' xiv. 376–377 (Abs.)

Physical Relations, 1890, 1891, 1892.

J. Trowbridge .	On Electrical Oscillations in Air, together with the Spectroscopic Study of the Motions of Molecules in Electrical Discharges. (May.)	'Proc. Amer. Acad.' xxvi. 325 (title).
L. H. Siertsema .	Der Jamin'sche Interferentialrefractometer und einige mit ihm ausgeführten Brechungsindicesbestimmungen. (Inaug. Dissert. Gröningen, 1890.)	'Beiblätter,' xiv. 801–803 (Abs.)

1891.

R. Nasini and T. Costa.	Ueber die Veränderungen des Refractions- und Dispersionsvermögens des Schwefels in seinen Verbindungen. (Regia Università degli Studi d. Roma. Instituto Chimico. Roma, Tipografia della R. Accad. d. Lincei, 1891, 147 pp.)	'Beiblätter, xvii. 111–115 (Abs.)
B. T. Geronyi .	Misura dell' indice di rifrazione d' un prisma. (Oct.)	'Riv. scient. industr.' xxiii. 221–226.

1892.

W. de W. Abney and E. R. Festing.	Colour Photometry. Part III. (Read Jan. 28.)	'Phil. Trans.' clxxxiii. A. 531–565.
F. Dussaud . .	Sur la réfraction et la dispersion du chlorate de soude cristallisé. (Read Feb. 4.)	'Arch. de Genève' [3], xxvii. 380–405, 521–535; 'Zeitschr. f. Kryst. u. Min.' xxiv. 619–621; 'Beiblätter,' xx. 23–24 (Abs.)
J. S. Ames . .	The Modern Spectroscope. I. The Concave Grating in Theory and Practice. (Feb.)	'Astron. and Astrophys.' xi. 28–42.
F. Maclean . .	Photographies spectrales obtenues avec un réseau de Rowland. (Read April 1.)	'Séances de la Soc. franç. de phys.' 1892, 165–166; 'Beiblätter,' xviii. 568 (Abs.)
F. Zecchini . .	Rifrazioni atomiche degli elementi rispetto alla luce gialla del sodio. (Read Sept. 4.)	'Rend. R. Accad. d. Lincei' [5], i. II. sem. 180–187; 'Beiblätter,' xvii. 115–116 (Abs.); 'Ber.' xxv. (Ref.), 936 (Abs.)
V. Schumann. .	Ueber eine neue ultraviolettempfindliche Platte, und die Photographie der Lichtstrahlen kleinster Wellenlängen. (Read Nov. 10.)	'Wien. Anz.' xxix. Jahrg. (1892), 230–231; 'Chem. News,' lxvi. 306 (Abs.)
J M. Eder . .	Ueber die Verwendbarkeit der Funkenspectrum verschiedener Metalle zur Bestimmung der Wellenlänge im Ultravioletten, mit Bezug auf das Spectrum des Sonnenlichtes, Drummond'schen, Magnesium- und electrischen Bogenlichtes. (Read Dec. 9.)	'Wien. Anz.' xxix. Jahrg. (1892), 264–265.

PHYSICAL RELATIONS, 1892, 1893.

H. O. G. Ellingen	Der Brechungsindex electrischer Strahlung in Alcohol. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xlviii. 108; 'Riv. scient. industr.' xxv. 71 (Abs.)
W J. Macé de Lépinay.	Sur la double réfraction du quartz ('Ann. Fac. des Sci. de Marseille,' No. 1).	'J. de Phys.' [3], i. 23–31; 'Beiblätter,' xvi. 288–289 (Abs.)

1893.

F. Paschen	Bolometrische Untersuchungen im Gitterspectrum. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], xlviii. 273–306.
F. Zecchini	Sul potere rifrangente del fosforo. II. Potere rifrangente degli acidi del fosforo e dei loro sali sodici. (Read Jan 8.)	'Rend. R. Accad. d. Lincei' [5], ii. I. sem. 31–38; 'Gazz. chim. ital.' xxiii. I. 109–120; 'Ber.' xxvi. (Ref.), 187–188 (Abs.)
J. H. Gladstone	Some Recent Determinations of Molecular Refraction and Dispersion. (Read Feb. 10.)	'Proc. Phys. Soc.' xii. 153–160; 'Chem. News,' lxvii. 94–95 (Abs.); 'Nature,' xlvii. 429 (Abs.)
H. A. Rowland	Gratings in Theory and Practice. Part I. (Feb.)	'Astron. and Astrophys.' xii. 129–149; 'Phil. Mag.' [5], xxxv. 397–419.
H. Ruoss	Bestimmung des Brechungsexponenten für Flüssigkeiten durch Spiegelablesung mit Fernrohr und Scala. (Feb.)	'Ann. Phys. u. Chem.' [N.F.], xlviii. 531–535; 'Zeitschr. f. physikal. Chem.' xi. 697 (Abs.)
J. W. Brühl	Die Spectrochemie des Stickstoffs. (Vorläufige Mittheilung.) (Read Mar. 25.)	'Ber.' xxvi. 806–809; 'Beiblätter,' xvii. 740 (Abs.)
H. Kayser and C. Runge.	Die Dispersion der Luft. (Read March 23.)	'Abhandl. Akad. Berlin,' 1893, 32 pp.; 'Nature,' xlviii. 60 (Abs.)
G. Carrara	Influenza degli alogeni sul valore ottico dei doppi legami. (Read April 30.)	'Rend. R. Accad. d. Lincei' [5], ii. I. sem. 353–358; 'Beiblätter,' xvii. 742–744 (Abs.)
A. Ghira	Sulla refrazione atomica del boro. (Read April 9.)	'Rend. R. Accad. d. Lincei' [5], ii. I. sem. 312–319; 'Gazz. chim. ital.' xxiii. I. 452–462; 'Ber.' xxvi. (Ref.), 573 (Abs.); 'Beiblätter,' xvii. 1047–1048 (Abs.); 'J. Chem. Soc.' lxiv. II. 517–518 (Abs.)
Th. Liebisch	Ueber die Spectralanalyse der Interferenzfarben optischzweiaxiger Krystalle. I. (April.)	'Gött. Nachr.' 1893, 265–266; 'Beiblätter,' xviii. 575–576 (Abs.)
H. A. Rowland	A New Table of Standard Wavelengths. (April.)	'Astron. and Astrophys.' xii. 321–347.
S. P. Langley	Latest Investigations with the Bolometer at the Astrophysical Observatory of the Smithsonian Institution. (Read May 27.)	'Astron. and Astrophys.' xiii. 41–44; 'Beiblätter,' xviii. 709 (Abs.)

PHYSICAL RELATIONS, 1893.

F. Zecchini	Sopra un notevole caso di accrescimento anomalo nel potere rifrangente delle base feniliche. (Read May 21.)	‘Rend. R. Accad. d. Lincei’ [5], ii. I. sem. 491–494; ‘Gazz. chim. ital.’ xxiii. II. 42–46; ‘Ber.’ xxvi. (Ref.), 863–864 (Abs.); ‘Beiblätter,’ xvii. 1048 (Abs.)
C. Trapesonzjanz	Ueber die Molecularrefraction stickstoffenthaltender Substanzen (Aldoxime und Ketoxime). (Read June 8.)	‘Ber.’ xxvi. 1428–1433; ‘Beiblätter,’ xviii. 335–336 (Abs.)
K. Zimányi	Die Hauptbrechungsexponenten der wichtigeren gesteinbildenden Mineralien bei Na-Licht. (July.)	‘Zeitschr. f. Kryst. u. Min.’ xxii. 321–358; ‘Beiblätter,’ xviii. 577–578 (Abs.)
J. F. Eijkman	Recherches réfractométriques. (Aug.)	‘Rec. des trav. chim. des Pays-Bas,’ xiii. 13–33; 157–197; ‘J. Chem. Soc.’ lxvii. II. 33, 65 (Abs.)
L. E. Jewell	An Absolute Scale of Intensity for the Lines of the Solar Spectrum and for Quantitative Analysis. (Aug.)	‘Astron. and Astrophys.’ xii. 815–821; ‘Beiblätter,’ xviii. 670 (Abs.)
H. Krone	Weiteres über Farbenphotogramme von Spectren. (Aug.)	‘Phot. Mittheil.’ xxx. 133–135, 148–150; ‘Beiblätter,’ xviii. 192 (Abs.)
W. M. Watts	Wave-length Tables of the Spectra of the Elements and Compounds. (Report of the Committee.) (Aug.)	‘Brit. Assoc. Rep.’ 1893, 387–437.
E. Lommel	Objective Darstellung von Interferenzerscheinungen in Spectralfarben. (Sept.)	‘Ann. Phys. u. Chem.’ [N.F.], l. 325–328; ‘Nature,’ xlix. 46 (Abs.)
R. Nasini	Coefficiente critico in relazione colla formula $(n-1)/d$. (Read Sept. 3.)	‘Rend. R. Accad. d. Lincei’ [5], ii. II. sem. 127–136; ‘Gazz. chim. ital.’ xxiii. 576–587; ‘Ber.’ xxvi. (Ref.), 928 (Abs.)
F. Zecchini	Sul potere rifrangente del fosforo. III. Potere rifrangente di alcune combinazioni organiche del fosforo. (Read Oct. 1.)	‘Rend. R. Accad. d. Lincei’ [5], ii. II. sem. 193–199; ‘Gazz. chim. ital.’ xxiv. I. 34–42; ‘Ber.’ xxvi. (Ref.), 929–930 (Abs.); ‘Beiblätter,’ xviii. 454–455 (Abs.); ‘J. Chem. Soc.’ lxvi. II. 221 (Abs.)
H. Dufet	Sur les indices de réfraction du spath d’Islande. (Read Nov. 9.)	‘Bull. Soc. franç. de Min.’ xvi. 149–178; ‘Séances de la Soc. franç. de phys.’ 1894, 95–96; ‘Beiblätter,’ xix. 638 (Abs.)
G. Lippmann	Photographie des couleurs. (Read Nov. 3.)	‘Séances de la Soc. franç. de phys.’ 1893, 248.
A. A. Michelson	Light Waves and their Application to Metrology. (Nov.)	‘Nature,’ xlix. 56–60.

PHYSICAL RELATIONS, 1893, 1894.

J. Joly	On the Influence of Temperature upon the Sensitiveness of the Photographic Dry Plate. (Read Dec. 20.)	'Proc. Roy. Soc. Dubl.' viii. (N.S.), 222; 'Nature,' xlix. 379 (Abs.)
V. Berghoff	Bestimmung der Brechungsexponenten von Schwefel und Phosphorlösungen im Schwefelkohlenstoff nach der Prismenmethode mit Fernrohr und Scala. (Dissert Marburg. 1893.)	'Beiblätter,' xviii. [5] (title).
J. F. Eijkman	Recherches réfractométriques	'Rec. trav. chim. des Pays-Bas,' xii. 157–197, 268–285; 'J. Chem. Soc.' lxvi. II. 173 (Abs.)
W. Zenker	Ueber die Entstehung der Farben im Lippman'schen Spectrum.	'Jahrb. f. Photogr.' vii. (1893), 114–121; 'Beiblätter,' xviii. 568 (Abs.)

1894.

G. Lippmann	Sur la théorie de la photographie des couleurs simples et composées par la méthode interférentielle. (Read Jan. 15.)	'C. R.' cxviii. 92–102; 'J. de Phys. [3], iii. 97–107.
R. Nasini	Sul potere rifrangente dei composti contenenti il carbonile. (Read Jan. 13.)	'Gazz. chim. ital.' xxiv. I. 157–169; 'J. Chem. Soc.' lxvi. II. 301–304 (Abs.)
J. Verschaffelt	Application du réfractomètre à l'étude des réactions chimiques. (Read Jan. 6.)	'Bull. Acad. Roy. de Belge,' [3], xxvii. 49–84; 'Beiblätter,' xviii. 746–747, 833–834 (Abs.)
P. Bary	Sur les indices de réfraction des dissolutions salines. (Read Feb. 2.)	'Séances de la Soc. franç. de phys.' 1894, 78.
H. Dufet	Indices du spath d'Islande. Discussion des résultats. (Read Feb. 16.)	'Séances de la Soc. franç. de phys.' 1894, 95–96.
G. Gennari	Sul potere rifrangente dell' alcool furanico, dell' acido piromucico e dei suoi eteri. (Read Feb. 4.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 123–129; 'Gazz chim. ital.' xxiv. I. 246–255; 'J. Chem. Soc. lxvi. II. 302 (Abs.); 'Ber.' xxvii. (Ref.), 426 (Abs.); 'Beiblätter,' xviii. 666 (Abs.)
J. H. Littlewood	Method for Determining the Refractive Index of a Solution which is available when the Solution is not Homogeneous. (Read Feb. 23.)	'Phil. Mag.' [5], xxxvii. 467–470; 'Beiblätter,' xviii. 905–906 (Abs.); 'Proc. Phys. Soc.' xiii. 74–76.
G. Moreau	Dispersion rotatoire magnétique infra-rouge du sulfure de carbone. (Feb.)	'Ann. chim. et phys.' [7], i. 227–258; 'Nature, xlix. 370 (Abs.)
R. Nasini and G. Carrara.	Sul potere rifrangente dell' ossigeno, dello zolfo, e dell' azoto nei nuclei heterociclici. (Read Feb. 22.)	'Gazz. chim. ital.' xxiv. I. 256–290; 'J. Chem. Soc.' lxvi. II. 302–303 (Abs.); 'Ber.' xxvii. (Ref.), 375–376 (Abs.); 'Beiblätter,' xviii. 834 (Abs.)

Physical Relations, 1894.

C. Runge . .	On a Certain Law in the Spectra of some of the Elements. (Feb.)	'Astron. and Astrophys.' xiii. 128–130.
A. Ghira . .	Rifrazione atomica di alcuni elementi. Potere rifrangenti delle combinazioni organo-metalliche. (Read March 18.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 297–300, 332–338; 'Gazz. chim. ital.' xxiv. I. 309–327; 'Beiblätter,' xviii. 906–907 (Abs.); 'J. Chem. Soc.' lxvi. I. 415–416 (Abs.): 'Ber.' xxvii. (Ref.), 377–378 (Abs.)
G. B. Rizzo . .	Sull' estensione della legge di Kirchhoff intorno alla relazione fra l' assorbimento e l'emissione della luce. (Read March 11.)	'Atti R. Accad. d. Torino,' xxix. 424–433; 'Beiblätter,' xviii. 835–836 (Abs.); 'Nature,' xlix. 606 (Abs.)
A. Ghira . .	Potere rifrangente delle combinazioni organo-metalliche. (Read April 15.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 391–393; 'Gazz. chim. ital.' xxiv. 324–327.
H. Jahn and G. Möller.	Ueber die dispersionsfreie Molecularrefraction einiger organischer Verbindungen. (April.)	'Zeitschr. f. physikal. Chem.' xiii. 385–397; 'Ber.' xxvii. (Ref.), 547 (Abs.); 'Beiblätter,' xviii. 831–833 (Abs.); 'J. Chem. Soc.' lxii. II. 265 (Abs.); 'Nature,' xlix. 582 (Abs.)
G. Gennari . .	Spettrochimica del cumarone e dell' indene. (Read May 20.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 499–503; 'Gazz. chim. ital.' xxiv. I. 468–474; 'Beiblätter,' xviii. 907 (Abs.)
A. König . .	Ueber die Anzahl der unterscheidbaren Helligkeitstufen und Spectralfarbentone. (May.)	'Nature,' l. 192 (Abs.); 'Ann. Phys. u. Chem.' [N.F.], liii. (Abhandl. phys. Ges.), 55 (Notice).
W. de W. Abney .	Measures of the Wave-lengths of Contrast Colours. (Read June 21.)	'Proc. Roy. Soc.' lvi. 221–229; 'Beiblätter,' xix. 179–180 (Abs.)
K. Ångström . .	Einige Bemerkungen anlässlich des bolometrischen Arbeiten von Fr. Paschen. (June.)	'Ann. Phys. u. Chem.' [N.F.], lii. 509–514; 'Proc. Phys. Soc.' xiii. 13 (Abs.)
A. Schuster . .	On Interference Phenomena. (June.)	'Phil. Mag.' [5], xxxvii. 509–545.
A. E. Tutton . .	Refractive Indices of the Sulphates of Potassium, Rubidium, and Cæsium. (Read June 7.)	'J. Chem. Soc.' lxv. 666–717.
L. Arons . .	Ueber Dielectricitätsconstanten fester und Brechungsexponenten geschmolzener Salze. (July.)	'Ann. Phys. u. Chem.' [N.F.], liii. 95–108; 'Proc. Phys. Soc.' xiii. 16 (Abs.)
F. Aymonnet . .	Sur les radiations calorifiques comprises dans la partie lumineuse du spectre. (Read July 2.)	'C. R.' cxix. 50–52; 'Beiblätter,' xviii. 908 (Abs.); 'Chem. News,' lxx. 62 (Abs.); 'Nature,' l. 287 (Abs.)

PHYSICAL RELATIONS, 1894.

H. Hallwachs .	Ueber Lichtbrechung und Dichte verdünnter Lösungen. (July.)	'Ann.Phys.u.Chem.'[N.F.], liii. 1–13; 'Nature,' l. 515 (Abs.)
C. Féry . .	Application de l'autocollimation à la mesure des indices de réfraction. (Read Aug. 13.)	'C. R.' cxix. 402–404.
J. E. Keeler . .	The Magnesium Spectrum as an Index to the Temperature of the Stars. (Aug.)	'Astr. Nachr.' cxxxvi. 77–80; 'Nature,' l. 364–365 (Abs.)
S. P. Langley .	On Recent Researches in the Ultra-red Spectrum. (Read Aug. 11.)	'Brit. Assoc. Rep.' 1894, 465–474; 'Nature,' li. 12–16 (Abs.)
„	Nouvelles recherches sur la région infra-rouge du spectre solaire. (Read Aug. 13.)	'C. R.' cxix 388–392; 'Beiblätter,' xviii. 1045–1046 (Abs.); 'Chem. News,' lxx. 114–115 (Abs.); 'Nature,' l. 420 (Abs.)
G. Moreau . .	De la périodicité des raies d'absorption des corps isotropes. (Read Aug. 20.)	'C. R.' cxix. 422–425.
F. Paschen . .	Ueber die Dispersion des Fluorits im Ultraroth. (Aug.)	'Ann.Phys.u.Chem.'[N.F.], liii. 301–333; 'Nature,' l. 635 (Abs.); 'Proc. Phys. Soc.' xiii. 14 (Abs.)
„ .	Ueber die Dispersion des Steinsalzes im Ultraroth. (Aug.)	'Ann.Phys.u.Chem.'[N.F.], liii. 337–342; 'Proc. Phys. Soc.' xiii. 15 (Abs.)
„ . .	Bolometrische Arbeiten. (Aug.) .	'Ann.Phys.u.Chem.'[N.F.], liii. 287–300; 'Proc. Phys. Soc.' xiii. 14 (Abs.)
G. J. Stoney . .	On the Cause of the Spurious Double Lines sometimes seen with Spectroscopes, and the Slender Appendages which accompany them. (Aug.)	'Brit. Assoc. Rep.' 1894, 583–585; 'Beiblätter,' xix. 423 (Abs.)
W. M. Watts . .	Wave-length Tables of the Spectra of the Elements and Compounds. (Report of Committee.) (Aug.)	'Brit. Assoc. Rep.' 1894, 248–267.
R. de Muynck .	Ueber die Brechungsexponenten von wässerigen Cadmiumsalzlösungen. (Sept.)	'Ann.Phys.u.Chem.'[N.F.], liii. 559–563; 'Ber.' xxviii. (Réf.), 7 (Abs.); 'J. Chem. Soc.' lxviii. II. 33 (Abs.); 'Proc. Phys. Soc.' xiii. 12 (Abs.)
H. Crew and R. Tatnall.	On a New Method of Mapping the Spectra of Metals. (Oct.)	'Phil. Mag.' [5], xxxviii. 379–386.
I. Zoppellari . .	Sulla rifrazione atomica del selenio. (Read Oct. 2.)	'Gazz. chim. ital.' xxiv. II. 396–407; 'Rend.R.Accad. d. Lincei' [5], iii. II. sem. 330–338; 'Ber.' xxviii. (Ref.), 54 (Abs.); 'Beiblätter,' xix. 487–488 (Abs.); 'J. Chem. Soc.' lxviii. II. 249–250 (Abs.)

PHYSICAL RELATIONS, 1894, 1895.

F. Paschen	Die Dispersion des Fluorits und der Ketteler'sche Theorie der Dispersion. (Nov.)	'Ann.Phys.u.Chem.'[N.F.], liii. 812–822; 'Proc. Phys. Soc.' xiii. 65 (Abs.)
V. Berghoff	Bestimmung der Brechungsexponenten von Schwefel- und Phosphorlösungen nach der Prismenmethode mit Fernrohr und Scala. (Nov.)	'Zeitschr. f. physikal. Chem.' xv. 422–436; 'Ber. xxviii. (Ref.), 101–102 (Abs.); 'Beiblätter,' xix. 327 (Abs.); 'Proc. Phys. Soc.' xiii. 106 (Abs.); 'J. Chem. Soc.' lxviii. II. 97 (Abs.)
J. Violle	Sur la température de l'arc électrique. (Read Dec. 3.)	'C. R.' cxix. 949–950; 'Chem. News,' lxx. 306 (Abs.)
A. Belopolsky	Ein Project zur Reproduction der Verschiebung von Spectrallinien bewegter Lichtquellen. (Dec.)	'Astr. Nachr.' cxxxvii. 34–36; 'Nature,' li. 233–234 (Abs.); 'Beiblätter,' xix. 418–419 (Abs.)
P. Bary	Variation de l'indice de réfraction avec le degré de concentration des solutions aqueuses des sels.	'J. Soc. franç. de phys.' 1894, 78.
B. Brunhès	Sur la vérification des quartz parallèles.	'J. de Phys.' [3], iii. 22–28; 'Proc. Phys. Soc.' xiii. 62–63 (Abs.)
A. Hupe	Bolometrische Arbeiten. Die Rotationsdispersion ultrarother Strahlen im Quartz. (Progr. Realschule Charlottenberg, 1894, 48 pp.)	'Beiblätter,' xix. 501–502 (Abs.)
A. A. Michelson	Les méthodes interférentielles en métrologie, et l'établissement d'une longueur d'onde comme unité absolue de longueur.	'J. de Phys.' [3], iii. 5–22; 'Proc. Phys. Soc.' xiii. 62 (Abs.)

1895.

E. Carvallo	Spectres calorifiques. (Jan.)	'Ann. de Chim. et Phys.' [7], iv. 1–79; 'Beiblätter,' xix. 566 (Abs.); 'Proc. Phys. Soc.' xiii. 223–224 (Abs.)
E. L. Nichols	The Distribution of Energy in the Spectrum of the Glow-Lamp. (Jan.)	'Phys. Review,' ii. 260–276; 'Beiblätter,' xix. 783–784 (Abs.); 'Proc. Phys. Soc.' xiii. 169 (Abs.)
H. A. Rowland	Preliminary Table of Solar Spectrum Wave-lengths. I.–X. (Jan.)	'Astrophys. J.' i. 29–46, 130–145, 222–231, 295–304, 360–369, 377–392; ii. 45–54, 109–118, 188–197, 306–315, 377–392; 'Beiblätter,' xix. 422 (Abs.)
M. Camichel	Absorption de la lumière dans les cristaux. (Read Feb. 15.)	'Bull. Soc. franç. de phys.' 1895, 50–56; 'Proc. Phys. Soc.' xiii. 167 (Abs.)

PHYSICAL RELATIONS, 1895.

A. König	Ueber die Anzahl der unterscheidbaren Spectralfarben und Helligkeitstreifen. (Feb.)	'Zeitschr. f. Psychol. u. Physiol. d. Sinnesorg.' viii. 375–380; 'Beiblätter,' xix. 642 (Abs.)
R. Neuhaus	Ueber die Photographie in natürlichen Farben. (Read Feb. 8.)	'Verhandl. Phys. Ges. Berl.' xiv. 17–24; 'Nature,' li. 503–504 (Abs.)
E. P. Lewis	The Infra-Red Spectra of the Elements. (Read April 25.)	'Johns Hopkins Univ. Circ.' xiv. 70 (Abs.); 'Beiblätter,' xix. 784 (Abs.)
V. Schumann	Zur Photographie der Lichtstrahlen kleinster Wellenlängen vom Luftspectrum jenseits 185·2 $\mu\mu$. (Read April 25.)	'Wien. Anz.' 1895, xi. 121–122.
A. König and H. Rubens.	Ueber die Energievertheilung im Spectrum des Triplex-Gasbrenners und der Amylacetatlampe. (Read May 10.)	'Verhandl. phys. Ges Berl.' xiv. 51 (Notice) 'Nature,' lii. 167 (Abs.)
E. Merritt	Ueber den Dichroismus von Kalkspath, Quarz und Turmalin für ultrarothe Strahlen. (May.)	'Ann.Phys.u.Chem.'[N.F.], lv. 49–64; 'Nature,' lii. 189 (Abs.)
C. Runge	Die Wellenlängen der ultravioletten Aluminiumlinien. (May.)	'Ann.Phys.u.Chem.'[N.F.], lv. 44–48; 'Nature,' lii. 189 (Abs.)
A. Schuster	Sur les spectres cannelés. (Read May 6.)	'C. R.' cxx. 987–989; 'Nature,' lii. 71 (Abs.)
F. Anderlini	Sopra alcuni questioni relative alla rifrazione atomica dell' ossigeno. (Read June 17.)	'Gazz. chim. ital.' xxv. II. 127–162; 'Ber.' xxviii. (Ref.), 973–974 (Abs.); 'J. Chem. Soc.' lxx. II. 229–230 (Abs.)
G. A. Borel	Recherches sur la réfraction et la dispersion des radiations ultraviolettes dans quelques substances cristallisées. (Read June 24.)	'Arch. de Genève' [3], xxxiv. 134–137, 230–249; 'C. R.' cxx. 1404–1406; 'Beiblätter,' xx. 42 (Abs.); 'Proc. Phys. Soc.' xiii. 34 (Abs.)
P. T. Clève	Sur la densité de l'hélium. (Read June 4.)	'C. R.' cxx. 1212; 'Nature,' li. 586; 'Chem. News,' lxxi. 201–202.
Sir J. Conroy	On the Refractive Index of Water at Temperatures between 0° and 10°. (Read June 20.)	'Proc. Roy. Soc.' lviii. 228–234; 'Nature,' lii. 455–456 (Abs.); 'Beiblätter,' xix. 881 (Abs.)
H. Ebert	On the Electromagnetic Nature of the Solar Radiation, and on a New Determination of the Temperature of the Sun. (June.)	'Astrophys. J.' ii. 55–57; 'Nature,' lii. 232 (Abs.)
J. H. Gladstone and W. Hibbert.	The Molecular Refraction of Dissolved Salts and Acids. (Read June 6.)	'J. Chem. Soc.' lxvii. 831–868; 'Proc. Chem. Soc.' xi. 120–121 (Abs.); 'Chem. News,' lxxi. 313 (Abs.); 'Beiblätter,' xx. 195 (Abs.); 'Ber.' xxix. (Ref.), 265 (Abs.)

E. P. Lewis	The Measurement of some Standard Wave-lengths in the Infra-Red Spectra of the Elements, I. II. (June.)	'Astrophys. J.' ii. 1–25, 106–108; 'Beiblätter,' xx. 28–29 (Abs.)
O. Wiener	Farbenphotographie durch Körperfarben und mechanische Farbenanpassung in der Natur. (June.)	'Ann. Phys. u. Chem.' [N.F.], lv. 225–281; 'Nature,' lii. 279 (Abs.)
W. F. Edwards	Some Notes on Molecular and Atomic Refraction. (July.)	'Amer. Chem. J.' xvii. 473–506; 'J. Chem. Soc.,' lxviii. II. 429–430 (Abs.)
J. F. Eijkman	Recherches réfractométriques. (July.)	'Rec. Trav. Chim. des Pays-Bas,' xiv. 185–202; 'J. Chem. Soc.' lxx. II. 133 (Abs.); 'Ber.' xxix. (Ref.), 73 (Abs.)
F. Paschen	Ueber Gesetzmässigkeiten in den Spectren fester Körper, und über eine neue Bestimmung der Sonnentemperatur. (Read July 6.)	'Nachr. Ges. Wiss. Göttingen' (1895), 294–304; 'Proc. Phys. Soc.' xiv. 44 (Abs.)
H. Rigollot	Action des rayons infra-rouges sur le sulfure d'argent. (Read July 15.)	'C. R.' cxxi. 164–166; 'Beiblätter,' xix. 891–892 (Abs.); 'Chem. News,' lxxii. 80 (Abs.); 'Proc. Phys. Soc.' xiii. 397 (Abs.); 'J. Chem. Soc.' lxx. II. 3 (Abs.); 'Nature,' lii. 312 (Abs.)
J. Bernstein	Das Beugungspectrum des quergestreiften Muskels bei der Contraction. (Aug.)	'Arch. f. d. gesammte Physiol.' lxi. 285–290; 'Naturw. Rundschau,' x. 540–541.
J. H. Pillsbury	A Scheme of Colour Standards. (Aug.)	'Nature,' lii. 390–392.
W. le C. Stevens	Recent Progress in Optics ('Rep. Amer. Assoc.') (Aug.)	'Nature,' liii. 233–238.
A. Witz	Eclairage par luminescence. (Read Aug. 5.)	'C. R.' cxxi. 306–308; 'Chem. News,' lxxii. 104–105.
Lord Rayleigh	The Refraction and Viscosity of Argon and Helium. (Sept.)	'Brit. Assoc. Rep.' 1895, 609 (Abs.); 'Chem. News,' lxxii. 224; 'Chem. Centralbl.' 1895, ii. 1112; 'Beiblätter,' xx. 192 (Abs.)
J. H. Gladstone	On Specific Refraction and the Periodic Law, with reference to Argon and other Elements. (Sept.)	'Brit. Assoc. Rep.' 1895, 609–610; 'Chem. News,' lxxii. 223–224.
G. D. Liveing and J. Dewar.	On the Refraction and Dispersion of Liquid Oxygen. (Sept.)	'Phil. Mag.' [5], xl. 268–272; 'Chem. News,' lxxii. 154; 'Beiblätter,' xx. 193 (Abs.); 'Ber.' xxix. (Ref.), 110 (Abs.)
W. M. Watts	Wave-length Tables of the Spectra of the Elements and Compounds (Report of Committee.) (Sept.)	'Brit. Assoc. Rep.' 1895, 273–340.

PHYSICAL RELATIONS, 1895.

A. Pflüger	Anomale Dispersionscurven einiger fester Farbstoffe. (Oct.)	'Ann. Phys. u. Chem. [N.F.], lvi. 412–432; 'Nature,' liii. 94 (Abs.); 'Proc. Phys. Soc.' xiii. 469 (Abs.)
J. W. Bruhl	Ueber das Wasserstoffhyperoxyd. Spectrometrische Bestimmungen. (Read Nov. 11.)	'Ber.' xxviii. 2858–2860; 'J. Chem. Soc.' lxx. II. 162–163 (Abs.)
A. A. Michelson	The Broadening of Spectral Lines. (Nov.)	'Astrophys. J.' ii. 251–263.
A. de F. Palmer, jun.	On the Wave-length of the D_3 Helium Line. (Nov.)	'Amer. J. Sci.' [3], l. 357–358; 'Phil. Mag.' [5], xl. 547–548; 'J. Chem. Soc.' lxx. II. 405 (Abs.); 'Beiblätter,' xx. 197 (Abs.); 'Chem. News,' lxxiii. 14 (Abs.); 'Nature,' liii. 190 (Abs.); 'Proc. Phys. Soc.' xiv. 159 (Abs.)
F. Paschen	Ueber die Wellenlängenscala des ultrarothen Flüssspathspectrums. (Nov.)	'Ann. Phys. u. Chem. [N.F.], lvi. 762–767.
W. H. Perkin	Influence of Temperature on the Refractive Power, and on the Refraction Equivalents of Acetylacetone and of Ortho- and Para-Toluidine. (Read Nov. 21.)	'J. Chem. Soc.' lxix. 1–6; 'Chem. News,' lxxii. 288 (Abs.); 'Beiblätter,' xx. 529–530 (Abs.)
F. Aymonnet	Sur le déplacement spectrale du maximum calorifique solaire. (Read Dec. 30.)	'C. R.' cxxi. 1139–1141; 'Nature,' liii. 239 (Abs.); 'Chem. News,' lxxiii. 47 (Abs.); 'Beiblätter,' xx. 537 (Abs.); 'Proc. Phys. Soc.' xiv. 44 (Abs.)
W. Hibbert	The Gladstone 'Law' in Physical Optics, and the True Volume of Liquid Matter. (Dec.)	'Phil. Mag.' [5], xl. 321–345; 'Proc. Phys. Soc.' xiii. 670–697; 'Beiblätter,' xx. 193–195 (Abs.)
H. A. Rowland	Preliminary Table of Solar Wave-lengths. XI.–XV. (Dec.)	'Astrophys. J.' iii. 141–146, 291–296, 356–373; iv. 106–115, 278–287.
R. W. Wood	Ueber die Absorptionsspectrum der Lösungen von Iod und Brom über der kritischen Temperatur.	'Zeitschr. f. physikal. Chem.' xix. 689–695; 'Phil. Mag.' [5], xli. 423–431; 'Beiblätter,' xx. 776 (Abs.); 'J. Chem. Soc.' lxx. II. 458 (Abs.); 'Ber.' xxix. (Ref.), 765 (Abs.)
E. von Aubel	Sur les densités et les indices de réfraction des mélanges de l'aldehyde ou de l'acétone avec l'eau.	'J. de Phys.' [3], iv. 478–482; 'Beiblätter,' xx. 195–196 (Abs.); 'Ber.' xxix. (Ref.), 72 (Abs.)
A. A. Michelson	The Metre in Terms of Wave-length of Light. (Bureau Internat. des Poids et Mesures, xi. 1–237.)	'Proc. Phys. Soc.' xiv. (Abs.), 102.

F. Perreau	Etude expérimentale de la dispersion et de la réfraction des gaz.	'J. de Phys.' [3], iv. 411–416; 'Beiblätter,' xx. 192–193 (Abs.); 'Proc. Phys. Soc.' xiv. 160–161 (Abs.)
J. Stscheglajew	Sur la dispersion anomale de la lumière dans les solutions de fuchsine.	'J. de Phys.' [3], iv. 546–551; 'Beiblätter,' xx. 272–273 (Abs.); 'Proc. Phys. Soc.' xiv. 125–126 (Abs.)
P. Zeeman	Messung des Brechungsindex des glühenden Platins ('Zittingsversl. Akad. Amsterdam,' 1895, 116–119).	'Beiblätter,' xx. 548 (Abs.)

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J. E. Keeler	Recent Researches bearing on the Determination of Wave-lengths in the Ultra-Red Spectrum. (Jan.)	'Astrophys. J.' iii. 63– 7.
Lord Rayleigh	On some Physical Properties of Argon and Helium. (Read Jan. 16)	'Proc. Roy. Soc.' lix. 198–208; 'Zeitschr. f. physikal. Chem.' xix. 364–372; 'Beiblätter,' xx. 312–313 (Abs.)
B. Walter	Ueber die Brechungsexponenten des festen Fuchsins. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], lvii. 394–396; 'Proc. Phys. Soc.' xiv. 124–125 (Abs.)
W. J. Humphreys and J. F. Mohler.	Effect of Pressure on the Wave-lengths of Lines in the Arc Spectra of Certain Elements. (Feb.)	'Johns Hopkins Univ. Circ.' xv. 35–37; 'Beiblätter,' xx. 533 (Abs.); 'Proc. Phys. Soc.' xiv. 282–283 (Abs.); 'Astrophys. J.' iii. 114–137.
M. Le Blanc and P. Rohland.	Ueber den Einfluss welchen die electrolytische Dissociation, der Wechsel des Aggregatzustandes und des Lösungsmittels auf das Lichtbrechungsvermögen einiger Stoffe ausüben. (Feb.)	'Zeitschr. f. physikal. Chem.' xix. 261–286; 'Beiblätter,' xx. 364–365 (Abs.); 'J. Chem. Soc.' lxx. II. 345 (Abs.); 'Ber.' xxix. (Ref.), 759–760 (Abs.)
A. J. Moses and E. Weinschenk.	Ueber eine einfache Vorrichtung zur Messung der Brechungsexponenten kleiner Krystalle mittelst Totalreflexion. (Feb.)	'Zeitschr. f. Kryst. u. Min.' xxvi. 150–155; 'Beiblätter,' xx. 872 (Abs.)
J. N. Lockyer	The Shifting of Spectral Lines. I. (March.)	'Nature,' liii. 415–417.
F. Perreau	Etude expérimentale de la dispersion et de la réfraction des gaz. (March.)	'Ann. Chim. et Phys.' [7], vii. 289–348; 'Beiblätter,' xx. 643–645 (Abs.)

PHYSICAL RELATIONS, 1896.

A. E. Tutton . .	Connection between the Atomic Weight of Contained Metals and the Crystallographical Characters of Isomorphous Salts. The Volume and Optical Relationships of the Potassium, Rubidium, and Cæsium Salts of the Monoclinic Series of Double Sulphates, $R_2M(SO_4)_2$, $6H_2O$. (Read March 19.)	'J. Chem. Soc.' lxix. 344–507.
C. Viola . .	Metodo per determinare l' indice di rifrazione della luce di un minerale nelle lamine sottili. (Read March 15.)	'Rend. R. Accad. d. Lincei' [5], v. II. sem. 212–216; 'Zeitschr. f. Kryst. u. Min.' xxvii. 430 (Abs.); 'Beiblätter,' xx. 874–875 (Abs.); 'Proc. Phys. Soc.' xiv. 237–238 (Abs.)
W. de W. Abney .	Note on Photographing Sources of Light with Monochromatic Rays. (Read April 30.)	'Proc. Roy. Soc.' lx. 13–15.
W. N. Hartley .	On the Temperature of Certain Flames. (Read April 23.)	'J. Chem. Soc.' lxix. 844–847.
G. Lippmann. .	On Colour Photography by the Interferential Method. (Read April 23.)	'Proc. Roy. Soc.' lx. 10–13; 'Chem. News,' lxxiii. 213–214.
,, . .	Colour Photography. (Lecture at Roy. Inst., April 17.)	'Chem. News,' lxxiv. 275–276, 285–286.
G. D. Liveing .	On Photographing the whole Length of a Spectrum at once. (Read April 27.)	'Proc. Phil. Soc. Camb.' ix. 141–142; 'Beiblätter,' xxi. 30 (Abs.); 'Nature,' liv. 94 (Abs.)
J. F. Mohler and L. E. Jewell.	On the Wave-length of some of the Helium Lines in the Vacuum Tube, and of D_3 in the Sun. (April.)	'Astrophys. J.' iii. 351–355; 'Beiblätter,' xxi. 336 (Abs.)
A. Schuster . .	Note on the Results of Messrs. Jewell, Humphreys, and Mohler. (April.)	'Astrophys. J.' iii. 292; 'Beiblätter,' xxi. 706 (Abs.)
W. H. Perkin .	On Magnetic Rotatory Power, especially of Aromatic Compounds. (Read May 18.)	'J. Chem. Soc.' lxix. 1025–1257; 'Beiblätter,' xxi. 254–256 (Abs.)
J. H. Gladstone .	The Relation between the Refraction of the Elements and their Chemical Equivalents. (Read June 4.)	'Proc. Roy. Soc.' lx. 140–146; 'Beiblätter,' xxi. 26–27 (Abs.)
F. Paschen . .	Ueber Gesetzmässigkeiten in den Spectren fester Körper. (June.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 455–493.
A. E. Tutton . .	Vergleichung der Resultate der Untersuchungen über die einfachen und doppelten K, Rb und Cs enthaltenenen Sulphate, und daraus abgeleitete Schlussfolgerungen über den Einfluss des Atomgewichte auf die Krystallographische Eigenschaften. (June.)	'Zeitschr. f. Kryst. u. Min.' xxvii. 252–265; 'Beiblätter,' xxi. 196 (Abs.)

PHYSICAL RELATIONS, 1896.

A. Hanke . .	'Ueber die Refractionsäquivalente der Elemente. (Read July 2.)	'Sitzungsb. Akad. Wien,' cv. II.a, 749–777; 'Wien. Anz.' xxxiii. 176 (Abs.)
A. Pflüger . .	Zur anomalen Dispersion absorbirender Substanzen. (July.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 670–673.
C. Viola. . .	Ueber eine Methode zur Bestimmung des Brechungsvermögen der Mineralien im Dünnschliff. (July.)	'Min. petr. Mitth.' (Tschermak), xvi. 150–154; 'Zeitschr. f. Kryst. u. Min.' xxvii. 430; 'Beiblätter,' xxi. 233 (Abs.)
A. Cotton . .	Recherches sur l'absorption et la dispersion de la lumière par les milieux doués du pouvoir rotatoire. (Aug.)	'Ann. Chim. et Phys.' [7], viii. 347–432; 'J. de Phys.' [3], v. 237–244, 290–303; 'Beiblätter,' xx. 882–883, xxi. 35–36 (Abs.)
A. König . .	Quantitative Bestimmungen an complementären Spectralfarben. (Read July 20.)	'Sitzungsb. Akad. Berl.' 1896, 945–949.
F. Aymonnet . .	Sur les maxima périodiques des spectres. (Read Sept. 28.)	'C. R.' cxxiii. 645–647; 'Chem. News,' lxxiii. 246; 'Beiblätter,' xxi. 31 (Abs.)
J. F. Mohler . .	The Effect of Pressure upon Wave-length. (Oct.)	'Astrophys. J.' iv. 175–181; 'Beiblätter,' xxi. 737 (Abs.)
E. F. Nichols. .	Das Verhalten des Quartzes gegen langwellige Strahlen, untersucht nach der radiometrischen Methode. (Read Oct. 22.)	'Sitzungsb. Akad. Berl.' 1896, 1183–1196; 'Phys. Review,' iv. 297–313; 'Ann. Phys. u. Chem.' [N.F.], lx. 401–417.
W. J. Humphreys .	A further Study of the Effects of Pressure on the Wave-lengths of Lines in the Arc Spectrum of Certain Elements. (Nov.)	'Astrophys. J.' iv. 249–262.
W. J. Pope . .	The Refractive Constants of Crystalline Salts. (Read Nov. 5.)	'J. Chem. Soc.' lxix. 1530–1546; 'Proc. Chem. Soc.' xii. (1896), 177–178 (Abs.); 'Zeitschr. f. Kryst. u. Min.' xxviii. 113–134: 'Chem. News,' lxxiv. 268–269 (Abs.); 'Chem. Centr.' 1897, I. 3–4 (Abs.); 'Beiblätter,' xxi. 347–348 (Abs.)
H. Rubens . .	Ueber das ultrarote Absorptionsspectrum von Steinsalz und Sylvin. (Read Nov. 6.)	'Verhandl. Phys. Soc. Berlin,' xv. 108–110; 'Beiblätter,' xxi. 130 (Abs.)
J. W. Brühl . .	Stereochemisch-spectrische Versuche. I. (Dec.)	'Zeitschr. f. physikal. Chem.' xxi. 385–413; 'Beiblätter,' xxi. 224–226 (Abs.)
A. Hagenbach .	Ein Versuch, die beiden Bestandtheile des Clèveïtgases durch Diffusion zu trennen. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], lx. 124–133.

PHYSICAL RELATIONS, 1896, 1897.

H. Rubens and E. F. Nichols.	Ueber Wärmestrahlen von grosser Wellenlänge. (Read Dec. 17.)	'Sitzungsb. Akad. Berl.' 1896, 1393–1400; 'Ann. Phys. u. Chem.' [N.F.], lx. 418–462; 'Phys. Review,' iv. 314–323; 'Nature,' lv. 329, 524 (Abs.)
J. F. Eijkman .	Recherches réfractométriques .	'Rec. trav. chim. des Pays-Bas,' xv. 52–60; 'Beiblätter,' xxi. 27–28 (Abs.)
V. A. Julius . .	Sur le quartz fondu, et les bandes d'interférence dans le spectre des fils de quartz.	'Arch. néerland.' xxix. 454–466; 'Beiblätter,' xx. 539 (Abs.)
O. Wallach . .	Ueber Refractions- und Dispersionsvermögen einer Reihe isomerer Kampfer ('Göttingen. Nachr.' 1896–69–73).	'Beiblätter,' xxi. 732–733 (Abs.)
P. Zeeman . .	Influence of Magnetism on the Light emitted by a Substance ('Zittingsversl. Akad. Amsterdam,' Oct. 31 and Nov. 21, 1896).	'Nature,' lv. 192, 347, 370 (Abs.)

1897.

J. W. Brühl . .	Spectrometrische Bestimmungen. (Read Jan. 25.)	'Ber.' xxx. 158–162; 'Chem. Centr.' 1897, I. 534 (Abs.); 'Beiblätter,' xxi. 511 (Abs.)
" . .	Hydrazin, Wasserstoffhyperoxyd, Wasser. (Read Jan. 25.)	'Ber.' xxx. 162–172; 'Beiblätter,' xxi. 407–409 (Abs.)
G. C. Comstock .	On the Application of Interference Methods to the Determination of the Effective Wave-length of Light. (Jan.)	'Astrophys. J.' v. 26–35 'Beiblätter,' xxi. 52 (Abs.); 'Science Abstr i. 12 (Abs.)
H. A. Rowland .	Preliminary Table of Solar Spectrum Wave-lengths. XVI. XVII. XVIII. (Jan.)	'Astrophys. J.' v. 11–25 109–118, 181–193; 'Phys Review,' v. 11–25.
G. Tammann . .	Ueber die Aenderung der Brechungscoefficienten bei der Neutralisation, der Bildung und Verdünnung von Lösungen. (Jan.)	'Zeitschr. f. physikal. Chem.' xxi. 537–544; 'Beiblätter,' xxi. 969–970 (Abs.)
J. Traube . .	Ueber die Atomrefractionen von Kohlenstoff, Wasserstoff, Sauerstoff und den Halogenen. (XVI. Abhandlung.) (Read Jan. 11.)	'Ber.' xxx. 39–42; 'Chem. Centr.' 1897, I. 403–404 (Abs.)
" . .	Ueber die Atomrefractionen des Stickstoffs. XVII. Mittheilung. (Read Jan. 11.)	'Ber.' xxx. 43–47; 'Chem. Centr.' 1897, I. 404 (Abs.)
—	On the Mode of Printing Maps of Spectra. (Discussion at the meeting of the Roy. Astron. Soc. on Jan 8.)	'Astrophys. J.' v. 216–217 (Abs.)

PHYSICAL RELATIONS, 1897.

F. Zecchini . .	Sul potere rifrangente delle mescolanze di due liquidi. (Read Jan. 8.)	'Gazz. chim. ital.' xxvii. 358–383; 'Chem. Centr.' 1897, I. 1193 (Abs.); 'Beiblätter,' xxi. 732 (Abs.); 'J. Chem. Soc.' lxxii. II. 470 (Abs.)
F. G. Kohl . .	Die assimilatorische Energie der blauen und violetten Strahlen des Spectrums. (Read. Feb. 26.)	'Ber. Deutsch. Bot. Ges.' xv. 111–124; 'Chem. Centr.' 1897, I. 867 (Abs.)
O. J. Lodge . .	The Influence of a Magnetic Field on Radiation Frequency. (Read Feb. 11.)	'Proc. Roy. Soc.' lx. 513–514.
J. B. Haycraft .	Luminosity and Photometry. (Read March 4.)	'Proc. Roy. Soc.' lxi. 49–50; 'Beiblätter,' xxi. 972 (Abs.); 'Nature,' lv. 525 (Abs.)
F. Paschen . .	Ueber Gesetzmässigkeiten in der Spectren fester Körper. (March.)	'Ann. Phys. u. Chem.' [N.F.], lx. 662–723; 'Nature,' liv. 311 (Abs.)
P. Zeeman . .	On the Influence of Magnetism on the Nature of the Light emitted by a Substance. (March.)	'Phil. Mag.' [5], xliii. 226–239; 'Astrophys. J.' v. 332–347.
J. W. Brühl . .	Spectrochemie des Stickstoffs. V. (April.)	'Zeitschr. f. physikal. Chem.' xxii. 373–409; 'J. Chem. Soc.' lxxii. II. 297 (Abs.); 'Beiblätter,' xxi. 586–588 (Abs.); 'Chem. Centr.' 1897, II. 81–83 (Abs.)
P. de Heen . .	Détermination de la partie du spectre qui développe la plus grande proportion d'infra-électricité. (Read April 5.)	'Bull. Acad. Belg.' [3], xxxiii. 321–323; 'Beiblätter,' xxi. 651 (Abs.)
N. Egoroff and N. Géorgiewsky.	Sur la polarisation partielle des radiations émis par quelques sources lumineuses sous l'influence du champ magnétique. (Read May 3.)	'C. R.' cxxiv. 949–951; 'Beiblätter,' xxi. 645–646 (Abs.)
G. Le Bon . .	Sur les propriétés de certaines radiations du spectre. (Read May 24.)	'C. R.' cxxiv. 1148–1151.
A. E. Tutton . .	Connection between the Crystallographical Characters of Isomorphous Salts and the Atomic Weight of the Metals contained. A comparative crystallographic study of the normal selenates of potassium, rubidium, and cæsium. (Read May 20.)	'J. Chem. Soc.' lxxi. 846–920; 'Proc. Chem. Soc.' xiii. 115–118 (Abs.); 'Chem. Centr.' 1897. II. 12, 562 (Abs.); 'Beiblätter,' xxii. 84–85 (Abs.)
F. L. O. Wadsworth	On the Resolving Power of Telescopes and Spectroscopes for Lines of Finite Width. (May.)	'Phil. Mag.' [5], xliii. 317–343.
W. H. Wright .	A Method of correcting the Curvature of Lines in the Spectroheliograph. (May.)	'Astrophys. J.' v. 325–327; 'Beiblätter,' xxii. 98 (Abs.)

Physical Relations, 1897.

S. Abati . .	Sul potere rifrangente e dispersivo del silicio nei suoi composti. (Read June 12.)	'Gazz. chim. ital.' xxvii.; II. 437–455; 'Chem. Centr.' 1898, I. 437–455.
A. St. C. Dunstan, M. E. Rice, and C. A. Kraus.	Preliminary Note on the Broadening of the Sodium Lines by Intense Magnetic Fields. (June.)	'Amer. J. Sci.' [4], iii. 472–474; 'Beiblätter,' xxi. 767 (Abs.)
J. H. Gladstone and W. Hibbert.	The Molecular Refraction of Dissolved Salts and Acids. II. (Read June 17.)	'J. Chem. Soc.' lxxi. 822–833; 'Beiblätter,' xxi. 966 (Abs.); 'Chem. Centr.' 1897. II. 459 (Abs.)
W. Huggins and F. W. Very.	On the Mode of Printing Maps of Spectra and Tables of Wave-length. (June.)	'Astrophys. J.' vi. 55–57.
O. J. Lodge . .	Further Note on the Influence of a Magnetic Field on Radiation Frequency. (Read June 3.)	'Proc. Roy. Soc.' lxi. 413–415; 'Nature,' lvi. 237–238.
A. Lumière and L. Lumière.	Application de la photographie à la mesure des indices de réfraction. (Read June 21.)	'C. R.' cxxiv. 1438–1440: 'Beiblätter,' xxi. 965 (Abs.); 'Nature,' lvi. 216 (Abs.)
C. F. Mabery and E. J. Hudson.	Refractive Power of Hydrocarbons (from Petroleum) and their Chlorine Derivatives. (June.)	'Amer. Chem. J.' xix. 482–485; 'J. Chem. Soc.' lxxii. I. 451–452 (Abs.); 'Chem. Centr.' 1897, II. 259 (Abs.)
D. W. Murphy .	Spectral Photometry. (June) .	'Astrophys. J.' vi. 1–21; 'Science Abstr.' i. 10 (Abs.)
J. S. Ames and W. J. Humphreys	Note on the Effect of Pressure upon the Series in the Spectrum of an Element. (June.)	'Johns Hopkins Univ. Circ.' xvi. 41–42; 'Phil. Mag.' [5], xliv. 119–122; 'Chem. News,' lxxvi. 21–22; 'Beiblätter,' xxi. 974–975 (Abs.); 'Chem. Centr.' 1897, II. 324 (Abs.)
W. J. Humphreys .	Changes produced by Pressure in the Wave Frequencies of the Lines of Emission Spectra of Elements. (June.)	'Johns Hopkins Univ. Circ.' xvi. 43–44; 'Beiblätter,' xxii. 219–221 (Abs.)
F. L. O. Wadsworth	Tables of the Resolving Power of Spectroscopes. (June.)	'Astrophys. J.' vi. 27–36.
P. Zeeman . .	Lignes doubles et triples dans le spectre, produites sous l'influence d'un champ magnétique extérieur. (Read June 21.)	'C. R.' cxxiv. 1444–1445.
" . .	Ueber Doublets und Triplets im Spectrum, verursacht durch äussere magnetische Kräfte. I. II. ('Zittingsversl. Akad. Amsterdam,' 1897, 13–18, 99–102.) (June.)	'Phil. Mag. [5], xliv. 55–60, 255–259; 'C. R.' cxxiv. 1444–1445; 'Beiblätter,' xxi. 765–767 (Abs.)
N. Egoroff and N. Géorgiewsky.	Sur la polarisation partielle des radiations lumineuses sous l'influence du champ magnétique. (Read July 5.)	'C. R.' cxxv. 16–17; 'Beiblätter,' xxi. 899–900 (Abs.)

Physical Relations, 1897.

J. Königsberger .	Ueber die Absorption von ultrarothen Strahlen in doppelbrechenden Krystallen. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxi. 687–704; 'Science Abstr.' i. 7 (Abs.)
C. E. Mendenhall and F. A. Saunders.	Preliminary Note on the Energy Spectrum of a Black Body. (July.)	'Phil. Mag.' [5], xliv. 136; 'Beiblätter,' xxi. 733 (Abs.)
J. H. Pillsbury .	Spectrum Colour Standards. (July.)	'Science' [2], vi. 89–91; 'Beiblätter,' xxi. 972 (Abs.)
J. Larmor . .	The Influence of Pressure on Spectral Lines. (Aug.)	'Brit. Assoc. Report,' 1897, 555–556.
W. Ramsay and M. W. Travers.	On the Refractivity of Certain Mixtures of Gases. (Aug.)	'Brit. Assoc. Report,' 1897, 587–588 (Abs.)
A. Schuster . .	Constitution of the Electric Spark. (Aug.)	'Brit. Assoc. Report,' 1897, 550; 'Electrician,' xxxix. 585 (Abs.); 'Beiblätter,' xxi. 1011 (Abs.)
W. M. Watts .	Wave-length Tables of the Spectra of the Elements and Compounds. (Report of Committee.) (Aug.)	'Brit. Assoc. Report,' 1897, 75–127.
W. König . .	Beobachtung des Zeeman'schen Phänomens. (Sept.)	'Ann. Phys. u. Chem.' [N.F.], lxii. 240–248.
P. Zeeman . .	Doublets and Triplets in the Spectrum, produced by External Magnetic Forces. (Sept.)	'Phil. Mag. [5], xliv. 55–60.
A. Cornu . .	Sur l'observation et l'interprétation cinématique des phénomènes découverts par M. le Dr. Zeeman. (Read Oct. 18.)	'C. R.' cxxv. 555–561; 'Science Abstr.' i. 8–9 (Abs.)
W. J. Humphreys .	Changes in the Wave Frequencies of the Lines of Emission Spectra of Elements; their dependence upon the elements themselves and upon the physical conditions under which they are produced. (Oct.)	'Astrophys. J.' vi. 169–232; 'Science Abstr.' i. 11–12 (Abs.)
A. A. Michelson .	Optical Radiation in a Magnetic Field. (Oct.)	'Astrophys. J.' vi. 48–54; 'Science Abstr.' i. 9 (Abs.)
A. Cotton . .	Procédé simple pour constater le changement de période de la lumière du sodium dans un champ magnétique. (Read Nov. 29.)	'C. R.' cxxv. 865–867.
H. A. Rowland .	Corrections and Additions to Professor H. A. Rowland's Table of Solar Spectrum Wave-lengths. (Nov.)	'Astrophys. J.' vi. 324–392.
A. Cotton . .	Sur la polarisation de la lumière émise par une flamme de sodium placée dans un champ magnétique. (Read Dec. 17.)	'C. R.' cxxv. 1169–1172.
W. Ramsay and M. W. Travers.	On the Refractivities of Air, Oxygen, Nitrogen, Argon, Hydrogen, and Helium. (Read Dec. 9.)	'Proc. Roy. Soc.' lxii. 225–232; 'Chem. Centr.' 1898, I. 429–430 (Abs.); 'Beiblätter,' xxii. 217 (Abs.)

Physical Relations, 1897.

A. Broca . .	Les variations de période des raies spectrales ('Rev. générale des Sciences,' viii. 935–939).	'Beiblätter, xxii. [29] (title).
B. Dijken . .	Die Molecularrefraction und Dispersion einiger wasserigen Salzlösungen in Zusammenhang mit der Dissociation. (Inaug. Dissert. Groningen, 1897, 67 pp.)	'Zeitschr. f. physikal. Chem.' xxiv. 81–113; 'Chem. Centr.' 1897, II. 383–384 (Abs.); 'Beiblätter,' xxi. 333, 970–971 (Abs.)
J. Ehlers . .	Die Absorption des Lichtes in einigen pleochroitischen Krystallen. (Inaug. Diss. Göttingen.) ('Neues Jahrb. f. Min. u. Geol.' (Beilage), xi. 259–317.	'Beiblätter,' xxii. 157–159 (Abs.)
O. Kamerlingh .	Een Brief van Prof. E. van Aubel betrekking hebbende op de proeven van den Heer Ch. Fièvez over de werking van het magnetisme op den aard der Spectra ('Zittingsversl. Akad. Amsterdam,' v. 356–359).	'Beiblätter,'. xxi. [39] (title).
K. R. Koch . .	Ueber das Verhalten der Dielectricitätsconstante und des Brechungsexponenten im magnetischen Felde.	'Ann. Phys. u. Chem.' [N.F.], lxiii. 132–136.
W. König . .	Einfache Demonstration des Zeeman'schen Phänomens.	'Ann. Phys. u. Chem.' [N.F.], lxiii. 268–272; 'Nature,' lvii. 402 (Abs.)
M. Konowalow .	Données concernant le pouvoir réfringeant des combinaisons azotées.	'J. Russ. Phys. Chem. Soc.' xxvii. 412–421; 'Zeitschr. f. physikal. Chem.' xxiii. 553–554; 'Beiblätter,' xxi. 966–968 (Abs.)
W. A. Kowalewski .	Sur le volume atomique et la réfraction atomique des chlorures des acides alkyle-phosphoreux.	'J. Russ. Phys. Chem. Soc.' xxix. 217–222; 'Chem. Centr.' 1897, II. 333–334; 'Beiblätter,' xxi. 968–969 (Abs.)
E. Prior . . .	Ueber H. Tornöe's spectrometrisch-aräometrischen Bieranalyse mit Hilfe des Differentialprisms von W. Hallwachs ('Forsch. Ber. über Lebensm. u. ihre Bez. z. Hyg.' iv. 304.)	'Chem. Centr.' 1898, I. 138.
H. Rubens . .	Ueber Wärmestrahlen von grosser Wellenlänge. ('Verhandl. Ges. Deutsch. Naturf. u. Aerzte,' ii. 54–56).	'Beiblätter,' xx. [85] (title).
V. Schumann .	Von den brechbarsten Strahlen und ihrer Photographiren-Aufnahme.	'Jahrbuch f. Photog.' xi. 24–25.
E. G. A. ten Siethoff	Verklaring van het door Dr. P. Zeeman gevonden lichtverschijnsel in het oog ('Zittingsversl. Akad., Amsterdam,' v. 351–355).	'Beiblätter,' xxi. [39] (title).

J. Stscheglajew .	Dispersion anomale dans les solutions de fuchsine.	'J. Russ. Phys. Chem. Soc.' xxviii. II. 41–55; 'Beiblätter,' xxi. 409 (Abs.)
H. T. Simon . .	Ueber ein neues photographischen Photometrirverfahren, und seine Anwendung auf die Photometrie des ultravioletten Spectralgebietes.	'Jahrb. f. Photogr.' xi. 38–55.
C. Soret, A. Borel, and E. Dumont.	Ueber die Brechungsindices der blauen und grünen Lösungen von Chromalaunen ('Arch. de Genève,' 1897, iv. 376–381).	'Beiblätter,' xxi. 731 (Abs.)
F. Swartz . .	Ueber den Atomrefractionsindex des Fluors' ('Bull. Akad. Belg.' [3], xxxiv. 293–307).	'Chem. Centr.' 1897, II. 1042–1044 (Abs.); 'Beiblätter,' xxii. 150 – 151 (Abs.)
H. Tornöe . .	Spectrometrisch - aräometrische Bieranalyse ('Pharm. Centr.-H.' xxxviii. 871–873).	'Chem. Centr.' 1898, I. 270–271.
F. L. O. Wadsworth.	Sur le pouvoir séparateur des luettes et des spectroscopes pour les raies de largeur finie.	'J. de Phys.' [3], vi. 409–425.
G. Weiss . .	Mesure des indices de réfraction .	'J. de Phys.' [3], vi. 681-690.
P. Zeeman . .	Ueber Doublets und Triplets im Spectrum, verursacht durch äussere magnetische Kräfte. III. ('Zittingsversl. Vet. Akad. Amsterdam,' 1897, 260–262.)	'Beiblätter,' xxii. 167 (Abs.)
,, . .	Measurements concerning Radiation Phenomena in the Magnetic Field. ('Zittingsversl. Vet. Akad. Amsterdam, 1897, 408–411).	'Phil. Mag.' [5], xlv. 197–442; 'Beiblätter,' xxii. 167 (Abs.)
Z. P. Bouman .	Emission und Absorption von Quarz und Glas bei verschiedenen Temperaturen. (Inaug. Dissert. Amsterdam, 1897, 91 pp.)	'Zittingsversl. Akad. Amsterdam,' 1896–7, 438–422; 'Beiblätter,' xxi. 589 (Abs.)

V.

FLUORESCENCE.

1887.

K. Noack . .	Verzeichniss fluorescirender Substanzen, nach der Farbe des Fluorescenzlichtes mit Literaturnachweisen ('Schriften d. Naturf.-Gesellsch. Marburg,' xii. 155 pp.)	'Beiblätter,' xii. 86 (Notice).

1895.

M. Berthelot . .	Observations sur l'argon; spectre de fluorescence. (Read April 16.)	'C. R.' cxx. 797 – 800; 'Ber.' xxviii. (Ref.), 409–410 (Abs.); 'Beiblätter,' xix. 567 (Abs.); 'J. Chem. Soc.' lxviii. II. 337–338 (Abs.); 'Chem. News,' lxxi. 212–213; 'Nature,' li. 622 (Abs.)

M. Berthelot . .	Nouvelles études sur la fluorescence de l'argon, et sur sa combinaison avec les éléments de la benzine. (Read June 24.)	'C. R.' cxx. 1386–7390; 'Ber.' xxviii. (Ref.), 1046 (Abs.); 'Beiblätter,' xix. 826–827 (Abs.); 'Chem. News,' lxxii. 13–14; 'J. Chem. Soc.' lxviii. II. 498–499 (Abs.); 'Proc. Phys. Soc.' xiii. 361 (Abs.); 'Nature, lii. 239 (Abs.), 255–256.
E. Dorn and H. Erdmann.	Ueber das von Berthelot beschriebene Fluorescenzspectrum des Argons. (July.)	'Ann. Chem. u. Pharm.' cclxxxvii. 230 – 232; 'Ber.' xxviii. (Ref.), 725 (Abs.); 'Beiblätter,' xix. 731 (Abs.); 'J. Chem. Soc.' lxx. II. 2 (Abs.); 'Chem. News,' lxxii. 78 (Abs.)
E. Wiedemann and G. C. Schmidt.	Ueber Luminescenz von festen Körpern und festen Lösungen. (Oct.)	'Ann. Phys. u. Chem.' [N.F.], lvi. 201 – 254; 'Nature,' liii. 94 (Abs.)
" " .	Fluorescenz des Natrium- und Kalium - Dampfes, und Bedeutung dieser Thatsache für die Astrophysik. (Read Nov. 12.)	'Sitzungsb. phys. med. Soc. Erlangen,' xxvii. 104–109; 'Nature,' liii. 250–251 (Abs.); 'Ann. Phys. u. Chem.' [N.F.] lvii. 447–453; 'J. Chem. Soc.' lxx. II. 346 (Abs.); 'Astrophys. J.' iii. 207–212.)
" " .	Fluorescenz und Verbindungsspectra organischer Dämpfe.	'Jahrb. f. Photogr.' x. 14–15.

1897.

" " .	Ueber das Fluorescenzspectrum des Natriums. (Read Feb. 5.)	'Verhandl. phys. Gesellsch. Berlin,' xvi. 37–40; 'Beiblätter,' xxi. 417 – 418 (Abs.)
H. Krone . .	Absorption des Lichtes, Fluorescenz, Phosphorescenz.	'Jahrb. f. Photogr.' xi. 81–87.

VI.

ASTRONOMICAL APPLICATIONS.

1891.

C. Dunér . .	Untersuchungen über die Rotation der Sonne. (Read Feb. 14.)	'Acta Soc. Sci. Upsala' [3], xiv. 1–78; 'Beiblätter,' xvi. 430 – 431 (Abs.)

1892.

A. M. Clerke . .	The New Star in Auriga. (April.)	'Contemporary Review,' April 1892; 'Astron. and Astrophys.' xi. 503–513; 'Beiblätter,' xvii. 207 – 208 (Abs.)

ASTRONOMICAL APPLICATIONS, 1892, 1893.

G. E. Hale . .	Solar Photography at the Kenwood Astrophysical Observatory. (May.)	'Astron. and Astrophys.' xi. 407–417, 603–604; 'Beiblätter,' xvii. 752 – 753 (Abs.)
M. von Konkoly .	Spectroscopische Beobachtungen an der Sternwarte von O'Gyalla in Ungarn. (Read June 20.)	'Math. u. Naturwiss. Ber. aus Ungarn,' x. 240–245.
G. E. Hale . .	The Ultra-violet Spectrum of the Solar Prominences. (Aug.)	'Astron. and Astrophys.' xi. 602; 'Beiblätter,' xvii. 126 (Abs.)
„ . .	A Remarkable Solar Disturbance. (Aug.)	'Astron. and Astrophys.' xi. 611–613; 'Beiblätter,' xvii. 126 (Abs.)
„ . .	Photographs of Solar Phenomena obtained with the Spectro-heliograph at the Kenwood Observatory. (Aug.)	'Astron. and Astrophys. xi. 603–604; 'Beiblätter,' xvii. 126 (Abs.)
E. von Gothard .	Das Spectrum des neuen Sternes in Auriga in Vergleich mit demjenigen einiger planetarischen Nebel. (Read Oct. 17.)	'Math. u. Naturwiss. Ber. aus Ungarn,' x. 246–249; 'Beiblätter,' xviii. 101–102 (Abs.)
E. C. Pickering .	Report of the Harvard College Observatory. (Oct.)	'Nature,' xlvii. 403–404 (Abs.)
W. W. Campbell .	The Spectrum of Nova Aurigæ in February and March 1892. (Nov.)	'Astron. and Astrophys.' xi. 799–811; 'Nature,' xlvii. 133 (Abs.)
G. E. Hale . .	Some Results and Conclusions derived from a Photographic Study of the Sun. (Nov.)	'Astron. and Astrophys.' xi. 811–815; 'Chem. News,' lxvii. 4–5 (Abs.); 'Beiblätter,' xvii. 753 (Abs.)
W. W. Campbell .	The Motion of Nova Aurigæ. (Nov.)	'Astron. and Astrophys.' xi. 881–882; 'Nature,' xlvii. 256 (Abs.)
W. Sidgreaves .	Note on the Revival of Nova Aurigæ. (Dec.)	'Astron. and Astrophys.' xi. 882–885; 'Nature,' xlvii. 256 (Abs.)
H. C. Vogel . .	Untersuchung über die Eigenbewegung der Sterne im Visionsradius auf spectrographischen Wege.	'Publ. d. Astrophys. Obs. Potsdam,' vii. I. Theil, No. 23, 1–166; 'Beiblätter,' xvii. 128–129 (Abs.)

1893.

W. W. Campbell .	The Spectra of Holmes's and Brookes's Comets. (Jan.)	'Astron. and Astrophys.' xii. 57; 'Nature,' xlvii. 235.
J. E. Keeler . .	Spectrum of Holmes's Comet. (1892, III.) (March.)	'Astron. and Astrophys.' xii. 272–273; 'Nature,' xlvii. 578 (Abs.)
H. C. Vogel . .	Ueber den neuen Stern im Fuhrmann. (Read March 16.)	'Abhandl. Akad. Berlin,' 1893, 60 pp.; 'Beiblätter,' xvii. 932–933 (Abs.)

ASTRONOMICAL APPLICATIONS, 1893.

J. E. Keeler . .	Visual Observations of the Spectrum of β Lyræ. (April.)	'Astron. and Astrophys.' xii. 350–361; 'Beiblätter,' xviii. 100–101 (Abs.); 'Nature,' xlvii. 616 (Abs.)
A. Belopolsky .	Le spectre de l'étoile variable β Lyræ. (Read May 12.)	'Bull. Acad. St. Petersburg' [4], xxxvi. 163–195.
,, .	Spectrum der 'Nova Aurigæ,' 1892, beobachtet in Pulkowa. (May.)	'Bull. Acad. St. Petersburg' [4], xxxv. 399–420; 'Nature,' xlix. 23 (Abs.)
H. Deslandres .	Sur la recherche de la couronne solaire en dehors des éclipses totales. (Read May 23.)	'C. R.' cxvi. 1184–1187; 'Beiblätter,' xviii. 672 (Abs.)
M. Fleming . .	Stars having Peculiar Spectra. (June.)	'Astron. and Astrophys.' xii. 170, 546–547, 810–811.
O. Knopf . .	Die Schmidt'sche Sonnentheorie und ihre Anwendung auf die Methode der spectroscopischen Bestimmung der Rotationsdauer der Sonne. (Habilitationschrift, June 1893, 44 pp.)	'Astr. Nachr.' cxxxiv. 105–120; 'Beiblätter,' xvii. 930–931 (Abs.)
A. D. Risteen .	The Sun's Motion through Space. (June.)	'Astron. J.' xiii. 74–75; 'Nature,' xlviii. 208–209 (Abs.)
G. Müller . .	Photometrische und spectroscopische Beobachtungen auf dem Gipfel des Säntis. (Publications des Astrophys. Observ. zu Potsdam, viii. I. 5.) (July.)	'Naturwiss. Rundschau,' viii. 325–327.
W. W. Campbell .	The Spectrum of the Rordame-Quénisset Comet. (Aug.)	'Astr. Nachr.' cxxxiii. 150–152; 'Nature,' xlviii. 379 (Abs.); 'Beiblätter,' xviii. 766 (Abs.)
,, .	The Spectrum of Comet *b* 1893. (Aug.)	'Astron. and Astrophys.' xii. 652–653.
,, .	The Nature of the Spectrum of Nova Aurigæ. (Aug.)	'Astron. and Astrophys.' xii. 722–730; 'Astr. Nachr.' cxxxiii. 337–343; 'Nature,' xlviii. 524 (Abs.)
J. E. Keeler . .	Wave-lengths of the Two Brightest Lines in the Spectrum of the Nebulæ. (Aug.)	'Astron. and Astrophys.' xii. 733–736; 'Beiblätter,' xviii. 566 (Abs.); 'Nature,' xlix. 18 (Abs.)
,, .	Observations of Comet *b* 1893. (Aug.)	'Astron. and Astrophys.' xii. 650–651; 'Nature,' xlviii. 401 (Abs.)
E. C. Pickering .	The Constitution of the Stars. (Oct.)	'Astron. and Astrophys.' xii. 718–722; 'Beiblätter,' xviii. 673 (Abs.)
W. H. S. Monck .	The Spectra and Proper Motion of Stars. (Nov.)	'Astron. and Astrophys.' xii. 811–812.

ASTRONOMICAL APPLICATIONS, 1893, 1894.

E. C. Pickering .	A New Star in Norma. (Nov.) .	'Astr. Nachr.' cxxxiv. 101–102; 'Beiblätter,' xviii. 768 (Abs.); 'Astron. and Astrophys.' xiii. 40–41; 'Nature,' xlix. 300 (Abs.)
" .	The Spectrum of Nova Normæ. (Nov.)	'Astr. Nachr.' cxxxiv. 101–102; 'Nature,' xlix. 162–163 (Abs.)
J. Wilsing . .	Ueber die Bestimmung von Bahnelementen einiger Doppelsterne aus spectroscopischen Messungen der Geschwindigkeitscomponenten. (Nov.)	'Astr. Nachr.' cxxxiv. 89–92; 'Beiblätter,' xviii. 673 (Abs.)
C. A. Young . .	Note on the Chromosphere Spectrum. (Oct.)	'Nature,' xlv. 28; 'Beiblätter,' xvii. 830 (Abs.)
W. W. Campbell .	Hydrogen Envelope of the Star D.M. +30° 36′ 39″. (Dec.)	'Astron. and Astrophys.' xii. 913–914; 'Nature,' xlix. 210 (Abs.)
H. Deslandres .	Sur la recherche de la partie de l'atmosphère coronale du soleil projetée sur la disque. (Read Dec. 26.)	'C. R.' cxvii. 1053–1056; 'Beiblätter,' xviii. 563 (Abs.)
T. E. Espin . .	Stars with Remarkable Spectra. (Dec.)	'Astr. Nachr.' cxxxiv. 123–128; 'Nature,' xlix. 183–184 (Abs.)
A. Belopolsky .	Les changements dans le spectre du β Lyræ.	'Mem. spettr. ital.' xxii. 101–111; 'Nature,' xlviii. 301 (Abs.)
E. Gothard . .	Studien über das photographische Spectrum der planetarischen Nebel und des neuen Sterns.	'Mem. spettr. ital.' xxi. 169–173; 'Beiblätter,' xvii. 754 (Abs.)
F. Krüger . .	Catalog der farbigen Sterne zwischen dem Nordpol und 23 Grad südlicher Declination, mit besonderer Berücksichtigung des Spectraltypens.	'Publications d. Sternwarte in Kiel,' viii. 145 pp.; Beiblätter,' xviii. 98 (Notice).

1894.

T. E. Espin . .	Report of the Wolsingham Observatory. (Jan.)	'Nature,' xlix. 300 (Abs.)
A. Belopolsky .	On the Motion of ζ Herculis in the Line of Sight. (Feb.)	'Astron. and Astrophys.' xiii. 130–136.
W. W. Campbell .	Spectrum of Nova Normæ. (Telegram received at Kiel, Feb. 15.)	'Astr. Nachr.' cxxxv. 311–312; 'Nature,' xlix. 397.
H. Deslandres .	Recherches spectrales sur la rotation et les mouvements des planètes. (Read Feb. 25.)	'C. R.' cxx. 417–425; 'Beiblätter,' xx. 35 (Abs.); 'Proc. Phys. Soc.' xiii. 165 (Abs.); 'Nature,' li. 422 (Abs.)
J. Fényi . .	On Two Great Protuberances. (Feb.)	'Astron. and Astrophys.' xiii. 122–128; 'Beiblätter,' xix. 173 (Abs.)
H. Kayser . .	Ueber den Einfluss der Spaltenweite auf das Aussehen der Kometenspectra. (March.)	'Astr. Nachr.' cxxxv. 1–10; 'Beiblätter,' xviii. 766–767 (Abs.)

ASTRONOMICAL APPLICATIONS, 1894.

W. H. Pickering .	A Study of Nova Aurigæ and Nova Normæ. (March.)	‘Astron. and Astrophys.’ xiii. 201–204 ; ‘Beiblätter,’ xix. 175 (Abs.)
W. W. Campbell .	Observations of the New Star in Norma. (April.)	‘Astr. Nachr.’ cxxxv. 131–132; ‘Nature,’ xlix. 586 (Abs.)
H. Deslandres .	Photographie de la chromosphère solaire. (Read April 16.)	‘C. R.’ cxviii. 842–844.
E. C. Pickering .	New Variable Stars in Sculptor, Scorpio, Ophiuchus, and Aquila. (April.)	‘Astr. Nachr.’ cxxxv. 161–164 ; ‘Nature,’ xlix. 608 (Abs.)
H. C. Vogel . .	Bemerkungen zu der Abhandlung des Herrn Prof. H. Kayser ‘Ueber den Einfluss der Spaltenweite auf das Aussehen der Kometenspectra.’ (April.)	‘Astr. Nachr.’ cxxxv. 105–108 ; ‘Beiblätter,’ xviii. 766–767 (Abs.)
M. Fleming . .	Stars having Peculiar Spectra. (May.)	‘Astr. Nachr.’ cxxxv. 195–198 ; ‘Nature,’ l. 37 (Abs.)
A. Fowler . .	Gale's Comet. (May) . . .	‘Nature,’ l. 36–37.
E. H. Hills . .	The Total Solar Eclipse of April 16, 1893. Report on Results obtained with the Slit Spectroscope. (Received March 7. Read May 10.)	‘Proc. Roy. Soc.’ lvi. 20–26 ; ‘Nature,’ l. 236 (Abs.)
H. Kayser . .	Ueber den Einfluss der Spaltweite auf das Aussehen der Kometenspectra. (May.)	‘Astr. Nachr.’ cxxxv. 221–224; ‘Nature,’ xlix. 489 (Abs.)
J. N. Lockyer .	Preliminary Report on the Results obtained with the Prismatic Camera during the Total Solar Eclipse of April 16, 1893. (Read May 10.)	‘Proc. Roy. Soc.’ lvi. 7–8 (Abs.); ‘Beiblätter,’ 914 (Abs.); ‘Nature,’ l. 118–119 (Abs.)
E. C. Pickering .	The New Star in Norma. (May) .	‘Astron. and Astrophys.’ xiii. 398; ‘Beiblätter,’ xix. 68 (Abs.)
W. W. Campbell .	The Wolf-Rayet Stars. (June) .	‘Astron. and Astrophys.’ xiii. 448–476; ‘Nature,’ l. 181 (Abs.); ‘Beiblätter,’ xix. 67–68 (Abs.)
" . .	Spectra of the Great Nebula of Orion and other well-known Nebulæ. (June.)	‘Astron. and Astrophys.’ xiii. 384–398, 494–501 ; ‘Nature,’ l. 254 (Abs.); ‘Beiblätter,’ xix. 68 (Abs.)
T. E. Espin . .	Catalogue of Stars with Remarkable Spectra. (June.)	‘Astr. Nachr.’ cxxxv. 265–274.
M. Fleming . .	Stars having Peculiar Spectra. (June.)	‘Astron. and Astrophys.’ xiii. 501–503.
J. E. Keeler . .	The Spectra of the Orion Nebula and of the Orion Stars. (June.)	‘Astron. and Astrophys.’ xiii. 476–493; ‘Nature,’ l. 254 (Abs.); ‘Beiblätter,’ xix. 68 (Abs.)

ASTRONOMICAL APPLICATIONS, 1894.

J. N. Lockyer	On the Photographic Spectrum of the Great Nebula in Orion. (Read June 21.)	'Proc. Roy. Soc.' lvi. 285–286 (Abs.); 'Astron. and Astrophys.' xiii. 574–575 (Abs.)
"	Preliminary Note on the Spectrum Changes in β Lyræ. (Read June 21.)	'Proc. Roy. Soc.' lvi. 278–285; 'Astron. and Astrophys.' xiii. 575–581.
F. Renz	Beobachtungen der Nova (T) Aurigæ. (June.)	'Astr. Nachr.' cxxxv. 389–394; 'Nature,' l. 254 (Abs.)
E. Demarçay	Sur la simplicité du samarium. (Read July 23.)	'C. R.' cxix. 163–164; 'Beiblätter,' xviii. 619 (Abs.)
H. Deslandres	Images spéciales du soleil données par les rayons simples, qui correspondent aux raies noires du spectre solaire. (Read July 9.)	'C. R.' cxix. 148–151; 'Chem. News,' lxx. 71 (Abs.); 'Nature,' l. 307–308 (Abs.); 'Beiblätter,' xix. 67 (Abs.)
J. Evershed	The Corona Spectrum. (July)	'Nature,' xlviii. 268; 'Beiblätter,' xviii. 563 (Abs.)
R. Lehman-Filhès	Ueber die Bestimmung einer Doppelsternbahn aus spectroscopischen Messungen den im Visionsradius liegenden Geschwindigkeitscomponenten. (July.)	'Astr. Nachr.' cxxxvi. 17–30.
H. Deslandres	Recherches sur les mouvements de l'atmosphère solaire. (Read Aug. 27.)	'C. R.' cxix. 457–460 'Beiblätter,' xix. 333 (Abs.); 'Nature,' l. 468 (Abs.)
W. Huggins	Note on the Spectrum of the Great Nebula in Orion. (Aug.)	'Astron. and Astrophys.' xiii. 568–569.
J. E. Keeler	The Magnesium Spectrum as an Index to the Temperature of the Stars. (Aug.)	'Astr. Nachr.' cxxxvi. 77–80; 'Beiblätter,' xix. 60 (Abs.). 'Nature,' l. 364–365 (Abs.)
H. C. Vogel	On the Spectrum of β Lyræ. (Aug.)	'Astron. and Astrophys.' xiii. 561–568.
A. Berberich	Neue Untersuchungen über Nebelspectra. (Sept.)	'Naturw. Rundschau,' ix. 477–479.
J. E. Keeler and J. Scheiner.	Linien im unteren roth-gelb-grünen Theile des Spectrums von β Orionis (Rigel.) (Sept.)	'Naturw. Rundschau,' ix. 476 (Abs.)
A. Belopolsky	Etude sur le spectre de l'étoile variable δ Cephei. (Read Oct. 12.)	'Bull. Acad. St. Petersburg' [5], i. 267–306; 'Nature,' li. 282 (Abs.)
"	Das Spectrum von δ Cephei. (Oct.)	'Astr. Nachr.' cxxxvi. 281–284; 'Astrophys. J.' i. 160–161; 'Beiblätter,' xx. 40 (Abs.); 'Nature,' li. 21 (Abs.)
A. Fowler	Mira Ceti. (Nov.)	'Nature,' li. 40.

ASTRONOMICAL APPLICATIONS, 1894, 1895.

J. N. Lockyer	The Sun's Place in Nature. (A course of lectures to working men, delivered in the Museum of Practical Geology, Nov.–Dec.)	'Nature,' li. 374–377, 396–399, 565–569, 590–592; lii. 12–14, 156–158, 204–207, 253–255, 327–329, 422–425, 446–450.
„	Observations of Sun-spot Spectra, 1879–94. (Read Nov. 22.)	'Proc. Roy. Soc.' lvii. 199–201; 'Nature,' li. 448–449; 'Beiblätter,' xx. 33 (Abs.)
A. Belopolsky	Ein Project zur Reproduction der Verschiebung von Spectrallinien bewegter Lichtquellen. (Dec.)	'Astr. Nachr.' cxxxvii. 34–36; 'Nature,' li. 233–234 (Abs.); 'Beiblätter,' xix. 418–419 (Abs.)
H. Deslandres	Sur la vitesse radiale de ζ Herculis. (Read Dec. 31.)	'C. R.' cxix. 1252–1254; 'Beiblätter,' xix. 431–432 (Abs.); 'Nature,' li. 260 (Abs.)
J. N. Lockyer	On the Photographic Spectrum of γ Cassiopeiæ. (Read Dec. 13.)	'Proc. Roy. Soc.' lvii. 173–177; 'Nature,' li. 425 (Abs.)
E. C. Pickering	Stars having Peculiar Spectra. (Dec.)	'Astr. Nachr.' cxxxvii. 71–74; 'Nature,' li. 304 (Abs.)
A. Belopolsky	Sur le renversement de la raie D_3 du spectre solaire.	'Mem. spettr. ital.' xxiii. 89–93; 'Naturw. Rundschau,' ix. 55 (Abs.); 'Beiblätter,' xix. 422–423 (Abs.)
A. Cornu	Spectroscopie solaire	'Annuaire du Bureau des Longitudes,' 1894, 169–172; 'Nature,' xlix. 397 (Abs.)
A. A. Michelson	On the Conditions which Affect the Spectro-photography of the Sun. (Jan.)	'Astrophys. J.' i. 1–9; 'Beiblätter,' xix. 428 (Abs.)
E. C. Pickering	Discovery of Variable Stars by their Photographic Spectra. (Jan.)	'Astrophys. J.' i. 27–28; 'Beiblätter,' xix. 431 (Abs.)

1895.

W. W. Campbell	Recent Changes in the Spectrum of Nova Aurigæ. (Jan.)	'Astrophys. J.' i. 49–51; 'Beiblätter,' xix. 432 (Abs.); 'Nature,' li. 347 (Abs.)
H. C. Vogel	Neuere Untersuchungen über die Spectra der Planeten. I. II. (Read Jan. 17.)	'Sitzungsb. Akad. Berl.' 1895, 5–25; 'Astrophys. J.' i. 196–209, 273–284; 'Beiblätter,' xix. 429 (Abs.); 'Proc. Phys. Soc.' xiii. 261–262 (Abs.)
H Poincaré	Observations au sujet de la communication précédente de M. Deslandres. (Read Feb. 25.)	'C. R.' cxx. 420–421; 'Proc. Phys. Soc.' xiii. 166 (Abs.)
J. Fényi	A Very Large Solar Protuberance Observed on Dec. 24, 1894. (March.)	'Astrophys. J.' i. 212–215; 'Beiblätter,' xx. 33 (Abs.)

ASTRONOMICAL APPLICATIONS, 1895.

W. Huggins	Note on the Atmospheric Bands in the Spectrum of Mars. (March.)	‘Astrophys. J.’ i. 193–195; ‘Beiblätter,’ xx. 36 (Abs.)
H. Deslandres	Rayonnement ultraviolet de la couronne solaire pendant l’éclipse totale du 16 avril 1893. (Read April 1.)	‘C. R.’ cxx. 707–710; ‘Beiblätter,’ xx. 33 (Abs.); ‘Proc. Phys. Soc.’ xiii. 222 (Abs.); ‘Nature,’ li. 576 (Abs.)
L. E. Jewell	The Spectrum of Mars. (April)	‘Astrophys. J.’ i. 311–317; ‘Beiblätter,’ xx. 36 (Abs.); ‘Nature,’ lii. 37 (Abs.)
H. Deslandres	Recherches spectrales sur les anneaux de Saturne. (Read May 27.)	‘C. R.’ cxx. 1155–1158; ‘Proc. Phys. Soc.’ xiii. 308–309 (Abs.); ‘Nature,’ lii. 144 (Abs.)
”	Comparaison entre les spectres du gaz de la clèvéite et de l’atmosphère solaire. (Read May 20.)	‘C. R.’ cxx. 1112–1114; ‘Beiblätter,’ xix. 568 (Abs.); ‘Chem. News,’ lxxii. 14–15; ‘Proc. Phys. Soc.’ xiii. 371 (Abs.); ‘J. Chem. Soc.’ lxviii. II. 431 (Abs.); ‘Nature,’ lii. 120 (Abs.)
T. E. Espin	Stars with Remarkable Spectra. (May.)	‘Astr. Nachr.’ cxxxvii. 369–376; ‘Nature,’ lii. 86 (Abs.)
M. Fleming	Stars having Peculiar Spectra. Eleven New Variable Stars. (May.)	‘Astrophys. J.’ i. 411–415.
J. E. Keeler	A Spectroscopic Proof of the Meteoric Constitution of Saturn’s Rings. (May.)	‘Astrophys. J. i. 416–427; ‘Beiblätter,’ xx. 38 (Abs.); ‘Nature,’ lii. 164–165 (Abs.)
A. Orbinsky	Nouvelle méthode de détermination des vitesses radiales des étoiles. (May.)	‘Astr. Nachr.’ cxxxviii. 9–12; ‘Nature,’ lii. 155 (Abs.); ‘Beiblätter,’ xx. 202 (Abs.)
W. W. Campbell	A Review of the Spectroscopic Observations of Mars. (June.)	‘Astrophys. J.’ ii. 28–44; ‘Beiblätter,’ xx. 37 (Abs.)
W. Huggins	Solar and Terrestrial Helium. (June.)	‘Chem. News,’ lxxi. 283; ‘Beiblätter,’ xix. 634–635 (Abs.)
J. E. Keeler	Conditions Affecting the Form of Lines in the Spectrum of Saturn. (June.)	‘Astrophys. J.’ ii. 63–68; ‘Beiblätter,’ xx. 200 (Abs.)
J. N. Lockyer	Spectrum of the Orion Nebula. (Read June 21.)	‘Phil. Trans.’ clxxxvi. A, 73–91; ‘Nature,’ li. 471–472 (Abs.)
H. Seeliger	Bemerkung über die Rotation des Saturnringes. (June.)	‘Astr. Nachr.’ cxxxviii. 99–102; Beiblätter, xx. 38 (Abs.)

ASTRONOMICAL APPLICATIONS, 1895.

G. E. Hale	Preliminary Note on the D_3 Line in the Spectrum of the Chromosphere. (July.)	'Astr. Nachr.' cxxxviii. 227–230; 'Nature,' lii. 327 (Abs.); 'Beiblätter,' xx. 198 (Abs.)
W. Huggins	On the Duplicity of the Solar Line D_3. (July.)	'Astr. Nachr.' cxxxviii. 229–230; 'Beiblätter,' xx. 198 (Abs.)
J. Janssen	Sur la présence de la vapeur d'eau dans l'atmosphère de la planète Mars. (Read July 29.)	'C. R.' cxxi. 233–237; 'Beiblätter,' xx. 36 (Abs.); 'Proc. Phys. Soc.' xiii. 326 (Abs.); 'Nature,' lii. 514 (Abs.)
W. W. Campbell	A Spectrographic Determination of Velocities in the System of Saturn. (Aug.)	'Astrophys. J.' ii. 127–135; 'Beiblätter,' xx. 201–202 (Abs.)
„	The Spectrum of Mars. (Aug.)	'Publications of the Astronomical Society of the Pacific,' vi. No. 27, 228–236; 'Nature,' li. 132 (Abs.)
F. Krüger	Spectroscopic Observations of Coloured Stars. (Aug.)	'Astrophys. J.' ii. 148–159.
W. W. Campbell	Observations of the B Band in Stellar Spectra. (Sept.)	'Astrophys. J.' ii. 163.
„	The Visible Spectrum of the Trifid Nebula. (Sept.)	'Astrophys. J.' ii. 161–162.
C. Runge and F. Paschen.	Helium and the Spectrum of Nova Aurigæ. (Sept.)	'Nature,' lii. 544.
A. Belopolsky	Spectrographische Untersuchungen des Saturnringes. (Oct.)	'Astr. Nachr.' cxxxix. 1–4, 210–214.
W. W. Campbell	Stars whose Spectra contain Bright and Dark Hydrogen Lines. (Oct.)	'Astrophys. J.' ii. 177–183; 'Nature,' liii. 15 (Abs.); 'Beiblätter,' xx. 372–373 (Abs.)
M. Fleming	Some New Variable Stars. (Oct.)	'Astrophys. J.' ii. 198–201.
„	A New Star in the Constellation Carina. (Oct.)	'Harvard Coll. Observ. Circ.' No. 1 (Oct. 30); 'Nature,' liii. 63 (Abs.)
J. E. Keeler	Note on the Rotation of Saturn's Rings. (Oct.)	'Astr. Nachr.' cxxxix. 5–6; 'Nature,' lii. 655 (Abs.); 'Beiblätter,' xx. 370 (Abs.)
J. N. Lockyer	Photographies des spectres des étoiles. (Read Oct. 21.)	'C. R.' cxxi. 546; 'Nature,' lii. 660 (Abs.)
H. C. Vogel	Ueber das Vorkommen der Linien des Clèveitgas-Spectrums in den Sternspectren, und über die Classification der Sterne vom ersten Spectraltypus. (Read Oct. 24.)	'Sitzungsb. Akad. Berl.' xl. 947–958; 'Proc. Phys. Soc.' xiv. 161–164 (Abs.); 'Beiblätter,' xx. 372 (Abs.); 'Astrophys. J.' ii. 333–346; 'Nature,' liii. 448–449 (Abs.)

Astronomical Applications, 1895, 1896.

A. Belopolsky	Recherches sur les déplacements des raies dans le spectre de Saturn et de son anneau. (In Russian.) (Nov.)	'Bull. Acad. St. Petersburg' [5], iii. 379–403; 'Beiblätter,' xx. 370 (Abs.)
H. Deslandres	Recherches spectrales sur l'étoile Altair. Reconnaissance d'un mouvement orbital et d'une atmosphère. (Read Nov. 4.)	'C. R.' cxxi. 629–632; 'Chem. News,' lxxii. 269 (Abs.); 'Nature,' liii. 38 (Abs.); 'Beiblätter,' xx. 372 (Abs.)
C. B. Frost	Note on a Differential Method of Determining the Velocity of Stars in the Line of Sight. (Nov.)	'Astrophys. J.' ii. 235–236; 'Beiblätter,' xx. 371 (Abs.)
J. N. Lockyer	On the Variable Stars of the δ Cephei Class. (Read Nov. 21.)	'Proc. Roy. Soc.' lix. 101–106; 'Nature,' liii. 262–263; 'Beiblätter,' xx. 700 (Abs.)
A. W. Roberts	Short Period Variability. (Nov.)	'Astrophys. J.' ii. 283–292; 'Nature,' liii. 162–163 (Abs.)
H. Deslandres	A Method of Investigating the Velocity of Stars in the Line of Sight with Small Instruments. (Read Dec. 13.)	'The Observatory,' xix. 49–52; 'Nature,' liii. 255–256 (Abs.)
M. Fleming	Stars having Peculiar Spectra. (Dec.)	'Astrophys. J.' ii. 354–359.
„	A New Star in Centaurus. (Dec.)	'Harvard Coll. Observ. Circ.' No. 4 (Dec. 20); 'Nature,' liii. 256.
G. E. Hale	On the Wave-length of the D_3 Line in the Spectrum of the Chromosphere. (Dec.)	'Astrophys. J.' ii. 384–385.
E. C. Pickering	A New Star in Carina. (Dec.)	'Astr. Nachr.' cxxxix. 119–120; 'Beiblätter,' xxi. 345 (Abs.)
H. Deslandres	Spectroscopie astronomique	'Report of the Paris Observatory,' 1895, 22–23; 'Nature, liv. 162 (Abs.)

1896.

A. Brester	The Variability of Red Stars. (Jan.)	'Knowledge,' xviii. 251–253; 'Nature,' liii. 248–249.
A. Belopolsky	Observations des raies renversées dans le spectre des protubérances, faites à Poulkova. (Feb.)	'Mem. spettr. ital.' xxv. 23–26.
G. E. Hale	Notes on the Application of Messrs. Jewell, Humphreys, and Mohler's Results to Certain Problems of Astrophysics. (Feb.)	'Astrophys. J.' iii. 156–161.
L. E. Jewell, J. F. Mohler, and W. J. Humphreys.	Note on the Presence of the 'Reversing Layer' in the Solar Atmosphere. (Feb.)	'Astrophys. J.' iii. 138–140; 'Beiblätter,' xx. 527 (Abs.)
J. Fényi	On Two Solar Protuberances, observed July 15 and Sept. 30, 1895. (March.)	'Astrophys. J.' iii. 192–200.

ASTRONOMICAL APPLICATIONS, 1896.

E. C. Pickering .	The Algol Variable, B.D. + 17° 4367. (March.)	‘Astrophys. J.’ iii. 200.
H. C. Vogel . .	Ueber das Spectrum von Mira Ceti. (Read March 26.)	‘Sitzungsb. Akad. Berl.’ 1896, 395–399; ‘Proc. Phys. Soc.’ xiv. (Abs.) 233–234; ‘Beiblätter,’ xxi. 345 (Abs.); ‘Nature,’ liii. 612 (Abs.)
L. E. Jewell . .	The Spectrum of Mars. (April) .	‘Astrophys. J.’ iii. 255–258; ‘Beiblätter,’ xxi. 342 (Abs.)
J. N. Lockyer .	The Total Eclipse of the Sun, April 16, 1893. (Read April 30.)	‘Proc. Roy. Soc.’ lx. 17–19 (Abs.); ‘Nature,’ liv. 46 (Abs.)
Th. Arendt . .	Die Schwankungen im Wasserdampfgehalte der Atmosphäre auf Grund spectroscopischer Untersuchungen. (May.)	‘Ann.Phys.u.Chem.’[N.F.], lviii. 171–204.
F. Maclean . .	Photographs of the Spectra of Twenty-three Helium Stars; also Photographs of the Spectra of Six Stars of the 3rd Magnitude, showing the Transition from Type to Type. (Read May 8.)	‘Monthly Not. R. A. S.’ lvi. 428–429; ‘Nature,’ liv. 158 (Abs.)
J. Trowbridge .	Carbon and Oxygen in the Sun. (May.)	‘Amer. J. Sci.’ [4], i. 329–333; ‘Phil. Mag.’ [5], xli. 450–454; ‘Nature,’ liv. 91–92 (Abs.)
J. N. Lockyer .	On the Unknown Lines observed in the Spectra of many Minerals. (Read June 4.)	‘Proc. Roy. Soc.’ lx. 133–140; ‘Beiblätter,’ xxi. 129–130 (Abs.)
E. C. Pickering .	Ten New Variable Stars. (June.)	‘Harvard Coll. Obs. Circ.’ No. 7; ‘Nature,’ liv. 206–207 (Abs.)
W. W. Campbell .	On Mr. Jewell’s Observations of the Spectrum of Mars. (July.)	‘Astrophys. J.’ iv. 79–80.
H. Deslandres .	Observations of the Total Solar Eclipse of April 16, 1893. (Report.) (July.)	‘Nature, liv. 301–302 (Abs.)
L. E. Jewell . .	Researches on the Solar Rotation. (Aug.)	‘Astrophys. J.’ iv. 138; ‘Nature,’ liv. 526 (Abs.)
E. C. Pickering .	Stars having Peculiar Spectra. (Aug.)	‘Astr. Nachr.’ cxli. 170; ‘Nature,’ liv. 404 (Abs.)
„ .	A New Spectroscopic Binary, μ_1 Scorpii. (Aug.)	‘Harvard Coll. Observ. Circ.’ No. 11, 2 pp.; ‘Nature,’ liv. 527 (Abs.)
J. E. Keeler . .	The Detection of the Lines of Water Vapour in the Spectrum of a Planet. (Sept.)	‘Astrophys. J.’ iv. 137–138.
M. Fleming . .	Stars having Peculiar Spectra. New Variable Stars in Crux and Cygnus. (Nov.)	‘Harvard Coll. Observ. Circ.’ No. 12, 2 pp.; ‘Nature,’ lv. 84 (Abs.)

ASTRONOMICAL APPLICATIONS, 1896, 1897.

J. N. Lockyer	Preliminary Report on the Results obtained with the Prismatic Camera during the Eclipse of 1893. (Read Nov. 19.)	'Proc. Roy. Soc.' lx. 271–272.
E. C. Pickering	Relative Motion of the Stars in the Line of Sight. (Nov.)	'Harvard Coll. Observ. Circ.' No. 13, 2 pp.; 'Nature,' lv. 137 (Abs.)
,,	A New Spectroscopic Binary in Puppis. (Nov.)	'Harvard Coll. Observ. Circ.' No. 14, 1 p.; 'Nature,' lv. 137 (Abs.)
M. Fleming	Stars having Peculiar Spectra. Eight New Variable Stars, in Cetus, Vela, Centaurus, Lupus, Scorpio, Aquila, and Pegasus. (Dec.)	'Astrophys. J.' iv. 354–359.
C. Runge and F. Paschen.	Oxygen in the Sun. (Dec.)	'Astrophys. J.' iv. 317–319; 'Nature,' lv. 303 (Abs.); 'Beiblätter,' xxi. 518 (Abs.)
	1897.	
A. Cornu	Spectres des étoiles, &c.	'Ann. Bureau des Longitudes,' 1896, 359–368; 'Proc. Phys. Soc.' xiv. 74–75 (Abs.)
A. Belopolsky	The Spectroscopic Binary α_1 Geminorum. (Jan.)	'Astrophys. J.' v. 1–7; 'Nature,' lv. 352 (Abs.)
H. Deslandres	Photographie d'une protubérance extraordinaire. (Read Jan. 25.)	'C. R.' cxxiv. 171–173; 'Beiblätter,' xxi. 519 (Abs.)
W. Huggins	Carbon in Bright-line Stars. (Jan.)	'Nature,' lv. 316.
Sir J. N. Lockyer	Celestial Eddies. (Jan.)	'Nature,' lv. 249–253.
,,	The Question of Carbon in Bright-line Stars. (Jan.)	'Nature,' lv. 304–305. 'Beiblätter,' xxii. 155 (Abs.)
,,	The Approaching Total Eclipse of the Sun. I.–VI. (Jan.–Sept.)	'Nature,' lvi. 154–157, 175–178, 318–321, 365–368, 392–395, 445–449.
E. C. Pickering	The Spectrum of ζ Puppis. (Jan.)	'Astrophys. J.' v. 92–94; 'Harvard Coll. Observ. Circ.' Nov. 16, 2 pp.; 'Nature,' lv. 352 (Abs.); 'Beiblätter,' xxi. 512 (Abs.)
L. E. Jewell	Oxygen in the Sun. (Feb.)	'Astrophys. J.' v. 99–100; 'Bleiblätter,' xxi. 518 (Abs.)
,,	The Coincidences of Solar and Metallic Lines. (Feb.)	'Astrophys. J.' iii. 89–113; 'Beiblätter,' xxi. 339 (Abs.)
H. Kayser	Spectrum of ζ Puppis. (Feb.)	'Astrophys. J.' v. 95–96; 'Beiblätter,' xxi. 521 (Abs.)

ASTRONOMICAL APPLICATIONS, 1897.

J. N. Lockyer	On the Iron Lines Present in the Hottest Stars. Preliminary Note. (Read Feb. 18.)	'Proc. Roy. Soc.' lx. 475–476; 'Nature,' lv. 452–453; 'Beiblätter,' xxi. 520 (Abs.); 'J. Chem. Soc.' lxxii. II. 469 (Abs.)
A. Fowler	The Chemistry of the Stars. (March.)	'Knowledge,' xx. 77–78; 'Nature,' lv. 447 (Abs.)
P. de Heen	Photographie de la chromosphère du soleil, et constitution de cet astre. (Read March 6.)	'Bull. Acad. Belg.' [3], xxxiii. 205–210.
J. N. Lockyer	On the Chemistry of the Hottest Stars. (Read March 25.)	'Proc. Roy. Soc.' lxi. 148–209.
F. McClean	Note on Comparative Photographic Spectra of Stars to the $3\frac{1}{2}$ Magnitude. (Read March 25.)	'Proc. Roy. Soc.' lxi. 213–216
E. C. Pickering	Stars having Peculiar Spectra. (March.)	'Harvard Coll. Observ. Circ.' No. 17, 2 pp.
A. Schuster	Note on the Chemical Constitution of the Stars. (Read March 25.)	'Proc. Roy. Soc.' lxi. 209–213.
„	Oxygen in the Sun. (March)	'Astrophys. J.' v. 162–163.
W. W. Campbell	Spectroscopic Notes. (April)	'Astrophys. J.' v. 233–242.
J. E. Keeler	Spectroscopic Observations of Mars in 1896–7. (May.)	'Astrophys. J.' v. 328–331.
P. de Heen	Note relative à la photographie de l'atmosphère solaire. (Read June 5.)	'Bull. Acad. Belg.' [3], xxxiii. 800–803.
Sir J. N. Lockyer	The Approaching Eclipse of the Sun. (June.)	'Nature,' lvi. 154–157, 175–178.
„	The Total Solar Eclipse of Aug. 9, 1896. Report on the Expedition to Kiö Island. (Read June 17.)	'Proc. Roy. Soc.' lxi. 444–445 (Abs.)
„	On the Classification of Stars of the δ Cephei Class. (Read June 17.)	'Proc. Roy. Soc.' lxi. 445–455.
„	On the Appearance of the Clèveite and other New Gas Lines in the Hottest Stars. (Read June 17.)	'Proc. Roy. Soc.' lxii. 52–67.
H. F. Newall	On some Spectroscopic Determinations of Velocity in the Line of Sight made at the Cambridge Observatory. (Read June 11.)	'Monthly Not. R. A. S.' lvii. 567–577.
C. A. Young	On the Reversing Stratum and its Spectrum, and on the Spectrum of the Corona. (Aug.)	'Astrophys. J.' vi. 155–157.
J. Evershed	The Corona Spectrum. (Sept.)	'Nature,' lvi. 444.
J. E. Keeler	Measurement by means of the Spectroscope of the Velocity of Rotation of the Planets. (Read Sept. 23.)	'Brit. Assoc. Report,' 1897, 729–731.
Sir W. Huggins	Sur les spectres des composantes colorées des étoiles doubles. (Read Oct. 11.)	'C. R.' cxxv. 512–514.

Sir W. Huggins .	Sur les spectres des étoiles principales du trapèze de la nébuleuse d'Orion. (Read Oct. 11.)	'C. R.' cxxv. 514–51
R. J. Aitken . .	Variations in the Spectrum of the Orion Nebula. (Nov.)	'Astrophys. J.' vi. 365.
A. Belopolsky .	New Investigation of the Spectrum of β Lyræ. (Nov.)	'Astrophys. J.' vi. 328–337.
E. C. Pickering .	Spectrum of a Meteor. (Nov.) .	'Harvard Coll. Obs. Circ.' (Nov. 20); 'Nature,' lvii. 101; 'Science Abstr.' i. 4 (Abs.)
J. R. Rydberg .	On the Constitution of the Red Spectrum of Argon. (Nov.)	'Astrophys. J.' vi. 338–348; 'Beiblätter,' xxii. 154 (Abs.)
W. W. Campbell .	On the Variations observed in the Spectrum of the Orion Nebula. (Nov.)	'Astrophys. J.' vi. 363–364; 'Science Abstr.' i. 4 (Abs.)
J. M. Schaeberle .	Observations of the Spectrum of the Orion Nebula. (Nov.)	'Astrophys. J.' vi. 364–365.
W. H. Wright .	Variations in the Spectrum of the Orion Nebula. (Nov.)	'Astrophys. J.' vi. 365–366.
A. Belopolsky .	Researches on the Spectrum of the Variable Star η Aquilæ. (Dec.)	'Astrophys. J.' vi. 393–399.
G. E. Hale . .	On the Presence of Carbon in the Chromosphere. (Dec.)	'Astrophys. J.' vi. 412–414; 'Nature,' lvii. 374 (Abs.)
H. F. Russell .	Motion of some Stars in the Line of Sight. (Report of the Cambridge Observatory.)	'Nature,' lvi. 270 (Abs.)

VII.

METEOROLOGICAL APPLICATIONS.

1891.

A. Crova . .	The Analysis of Diffused Light. ('Amer. Meteorol. Journ.' Nov. 1891.)	'Nature,' xlv. 189–190 (Abs.)

1892.

A. Fowler . .	Spectrum of Lightning. (July) .	'Nature,' xlvi. 268; 'Beiblätter,' xvii. 125–126 (Abs.)

1893.

G. Müller . .	Photometrische und spectroscopische Beobachtungen angestellt auf dem Gipfel des Säntis.	'Publ. d. Astrophys. Obs. Potsdam,' viii. 1–101; 'Beiblätter,' xvii. 1063–1065 (Abs.)

1894.

G. Meyer . .	Ein Versuch das Spectrum des Blitzes zu photographiren (Feb.)	'Ann. Phys. u. Chem.' [N.F.], li. 415–416; 'Nature,' xlix. 427 (Abs.); 'Phil. Mag.' [5], xxxvii. 420–421 (Abs.)

M. Berthelot . .	Remarques sur les spectres de l'argon et de l'aurore boréale. (Read March 25.)	'C. R.' cxx. 662–663; 'Ber.' xxviii. (Ref.), 318 (Abs.); 'Beiblätter,' xix. 567 (Abs.); 'Proc. Phys. Soc.' xiii. 289 (Abs.); 'J. Chem. Soc.' lxviii. II. 337 (Abs.); 'Nature,' li. 552 (Abs.)
O. Simong . .	Ueber periodische Aufnahmen des Sonnenspektrums vom Gipfel des Piks von Teneriffa (3711 m.) ('Verhandl. Ges. Naturf. u. Aerzte,' II. 1. Hälfte (1895), 85.)	'Beiblätter,' xix. [59] (title)

1896.

A. Ricco . .	Righe spettrali atmospheriche osservate sull' Etna, a Nicolosi in Catania. (June.)	'Mem. spettr. ital.' xxv. 127–134; 'Beiblätter,' xx. 978 (Abs.); 'Nature,' liv. 280–281 (Abs.)
L. E. Jewell . .	The Determination of the Relative Quantities of Aqueous Vapour in the Atmosphere by Means of the Absorption Lines of the Spectrum. (Dec.)	'Astrophys. J.' iv. 324–342; 'Nature,' lv. 258 (Abs.)

1897.

,, . .	Dr. Arendt's Spectroscopic Investigation of the Variation of Aqueous Vapour in the Atmosphere. (April.)	'Astrophys. J.' v. 279–281.

VIII.

CHEMICAL RELATIONS.

1885.

T. G. Eakins . .	On Allanite and Gadolinite ('Proc. Colorado Sci. Soc.' ii. 1885).	'Chem. News,' liii. 282; 'J. Chem. Soc.' l. 779–780 (Abs.)

1890.

G. Henslow . .	A Contribution to the Study of the Relative Effects of Different Parts of the Solar Spectrum on the Assimilation of Plants ('Proc. Linnæan Soc.' Nov. 6, 1890).	'Nature,' xliii. 72 (title).

1891.

J. W. Brühl . .	Untersuchungen über die Terpene und deren Abkömmlinge ('Abhandl.' III. IV.) (Read Oct. 29, Nov. 18.)	'Ber.' xxiv. 3373–3416, 3701–3737; 'Beiblätter,' xvii. 30–32 (Abs.)

1892.

,, . .	Untersuchungen über die Terpene und deren Abkömmlinge ('Abhandl.' VIII. IX.) (Read May 23.)	'Ber.' xxv. 1788–1796, 1796–1813; 'Beiblätter,' xvii. 30–32 (Abs.)

CHEMICAL RELATIONS, 1892, 1893.

J. W. Brühl . .	Ueber Dipropargyl und Benzol. (Read July 20.)	'Ber.' xxv. 2638–2646
N. Caro . . .	Ueber Oxyaurine und Oxyaurincarbonsäuren. II. Mittheilung. (Read Aug. 11.)	'Ber.' xxv. 2671–2675.
R. Nietski and A. Bossi.	Zur Kenntniss der Oxazinfarbstoffe. (Read Oct. 6.)	'Ber.' xxv. 2994–3005.
W. N. Hartley .	Methods of Observing the Spectra of easily Volatile Metals and their Salts, and of Separating their Spectra from those of the Alkaline Earths. (Read Dec. 1.)	'J. Chem. Soc.' lxiii. 138–141; 'Chem. News,' lxvi. 313 (Abs.)

1893.

T. W. Richards .	A Revision of the Atomic Weight of Barium. (Read Jan. 11.)	'Proc. Amer. Acad.' xxviii. 1–30; 'Chem. News,' lxviii. 232–233, 269–271, 283–284.
J. M. Eder and E. Valenta.	Ueber das Emissionspectrum der elementaren Silicium, und den spectrographischen Nachweis dieses Elementes. (Read Jan. 19.)	'Wien. Anz.' xxx. (1893), 19–21.
G. Krüss . .	Some Remarks on the Examination of the Rare Gadolinite Earths, and in particular on Determining the Equivalents of these Earths by converting the Oxide into the Sulphate. (Jan.)	'Chem. News,' lxvii. 32–33, 40–42.
J. Parry. . .	The Spectrum of Iron and the Periodic Law. (Jan.)	'Nature,' xlv. 253–255; 'Beiblätter,' xvii. 748–749 (Abs.)
J. W. Brühl . .	Untersuchungen über asymmetrische Bicarbonsäuren. (Read Feb. 6.)	'Ber.' xxvi. 337–345.
„ . .	Spectrochemie des Stickstoffs. I. (Vorläufige Mittheilung.) (Read Mar. 27.)	'Ber.' xxvi. 806–809.
G. Carrara .	Sul tiophosgene polimero. (Read May 7.)	'Rend. R. Accad. d. Lincei' [5], ii. I. sem. 421–425; 'Beiblätter,' xviii. 334–335 (Abs.)
G. Gennari . .	Spettrochimica del cumarone e dell' indene. (Read May 20.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 499–503; 'Gazz. chim. ital.' xxiv. I. 468–474; 'Beiblätter,' xviii. 907 (Abs.)
C. Trapesonzjanz .	Ueber die Molecularrefraction stickstoffenthaltender Substanzen (Aldoxime und Ketoxime). Read June 8.)	'Ber.' xxvi. 1428–1433; 'Beiblätter,' xviii. 335–336 (Abs.)
C. Graebe and A. Philips.	Ueber Oxyderivate des Anthrachinolinchinon. (Sept.)	'Ann. Chem. u. Pharm.' cclxxvi. 21–35; 'J. Chem. Soc.' lxiv. I. 670–671 (Abs.)

CHEMICAL RELATIONS, 1893, 1894.

J. W. Brühl . .	Ueber einige Eigenschaften und die Constitution des freien Hydroxylamins und seine Homologen. Spectrochemie des Stickstoffs. II. (Read Oct. 14.)	'Ber.' xxvi. 2508–2520.
V. Schumann .	Ueber ein neues Verfahren zur Herstellung ultraviolettempfindliche Platten. (Read Oct. 12.)	'Sitzungsb. Akad. Wien,' cii. II.a, 994–1024; 'Beiblätter,' xviii. 456–457 (Abs.)
F. Tiemann and P. Krüger.	Ueber Veilchenaroma. (Read Oct. 9.)	'Ber.' xxvi. 2675–2708.
F. Tiemann and Fr. W. Semmler.	Ueber Verbindungen der Citral- (Geraniol-)Reihe. (Read Oct. 9.)	'Ber.' xxvi. 2708–2729.

1894.

J. Verschaffelt .	Application du réfractomètre à l'étude des réactions chimiques. (Read Jan. 6.)	'Bull. Acad. Roy. de Belge,' [3], xxvii. 49–84; 'Beiblätter,' xviii. 746–747, 833–834 (Abs.)
R. Nasini and F. Anderlini.	Sul potere rifrangente dei composti continenti il carbonile. (Read Jan. 21.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 49–58; 'Gazz. chim. ital.' xxiv. I. 157–169; 'Ber.' xxvii. (Ref.), 244 (Abs.); 'Beiblätter,' xviii. 665 (Abs.)
R. Nasini and G. Carrara.	Sul potere rifrangente dell' ossigeno, dello zolfo, e dell' azoto nei nuclei eterociclici. (Read Feb. 22.)	'Gazz. chim. ital.' xxiv. I. 256–290; 'Zeitschr. f. physikal. Chem.' xvii. 539–544; 'Proc. Phys. Soc.' xiii. 397 (Abs.); 'J. Chem. Soc.' lxvi. II. 302–303 (Abs.); 'Ber.' xxvii. (Ref.), 375–376 (Abs.); 'Beiblätter,' xviii. 834 (Abs.)
J. W. Brühl . .	Neue Beiträge zur Frage nach der Constitution des Benzols. (Read Mar. 27.)	'J. prakt. Chem.' [2], xlix. 201–294; 'Ber.' xxvii. 1065–1083; 'Nature,' xlix. 614 (Abs.); 'J. Chem. Soc.' lxvi. I. 366–367 (Abs.)
A. Ghira . .	Potere rifrangente delle combinazioni organo-metalliche. (Read April 15.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 391–393; 'Gazz. chim. ital.' xxiv. I. 324–327; 'Beiblätter,' xviii. 906–907 (Abs.)
G. Gennari . .	Spettrochimica del camarone e dell' indene. (Read May 10.)	'Rend. R. Accad. d. Lincei' [5], iii. I. sem. 499–503; 'Gazz. chim. ital.' xxiv. I. 468–474.
H. A. Rowland .	The Separation of the Rare Earths. (May.)	'Johns Hopkins Univ. Circular,' xiii. 73–74; 'Chem. News,' lxx. 68–69; 'J. Chem. Soc.' lxvi. II. 449–550 (Abs.)

A. de Gramont .	Sur le spectre de lignes du soufre, et sur sa recherche dans les composés métalliques. (Read July 2.)	'C. R.' cxix. 68–70; 'Beiblätter,' xviii. 912 (Abs.); 'Chem. News,' lxx. 49 (Abs.); 'J. Chem. Soc.' lxvi. II. 434–435 (Abs.)
W. Crookes . .	The Separation of the Rare Earths. (Aug.)	'Chem. News,' lxx. 81–82.
W. N. Hartley .	New Methods of Spectrum Analysis, and on Bessemer Flame Spectra. (Aug.)	'Brit. Assoc. Rep.' 1894, 610–611; 'Beiblätter,' xx. 26 (Abs.)
Mecke and Wimmer	Nachweise von Blutflecken. (Nov.)	'Zeitschr. f. anal. Chem.' xxxiv. 129–131; 'Chem. News,' lxxi. 238.
C. Haacke . .	Spectrophotometrische Untersuchungen über die Einwirkung von Salzsäure auf einige Substitutionsproducte des Fuchsins. (Diss. Tübingen, 1894, 49 pp.)	'Beiblätter,' xx. 64 (title).

1895.

A. Étard . .	Pluralité des chlorophylles. Deuxième chlorophylle isolée dans la luzerne. (Read Feb. 11.)	'C. R.' cxx. 328–331; 'J. Chem. Soc.' lxviii. I. 389 (Abs.)
E. Schunck . .	Contributions to the Chemistry of Chlorophyll. (Read Feb. 14.)	'Proc. Roy. Soc.' lvii. 314–322.
W. Ramsay . .	Discovery of Helium. (Read Mar. 27.)	'J. Chem. Soc.' lxvii. 1107–1108; 'Chem. News,' lxxi. 151; 'Ber.' xxviii. (Ref.), 839 (Abs.); 'Beiblätter,' xix. 624 (Abs.)
P. F. Clève . .	Sur la présence de l'hélium dans la clèvéite. (Read April 16.)	'C. R.' cxx. 834; 'Ber.' xxviii. (Ref.), 373 (Abs.); 'Nature,' li. 622–623 (Abs.); 'Chem. News,' lxxi. 212.
H. Moissan . .	Action du fluor sur l'argon. (Read May 9.)	'Proc. Roy. Soc.' lviii. 120–121.
A. de Gramont .	Analyse spectrale directe de minéraux. (June.)	'Bull. Soc. franç. de Min.' xviii. 171–374.
G. Krüss and H. Krüss.	Eine neue Methode der quantitativen Spectralanalyse. (June.)	'Zeitschr. f. anorg. Chem.' x. 31–43.
A. de Gramont .	Sur l'analyse spectrale directe des minéraux et de quelques sels fondus. (Read July 8.)	'C. R.' cxxi. 121–123; 'Beiblätter,' xx. 30–31 (Abs.); 'J. Chem. Soc.' lxviii. II. 470–471 (Abs.); 'Chem. News,' lxxii. 103 (Abs.)
M. Konowalow .	Nitrirende Wirkung der Salpetersäure auf den Charakter gesättigten Verbindungen besitzende Kohlenwasserstoffe und deren Derivate. (Read July 29.)	'Ber.' xxviii. 1852–1865.
H. Rigollot . .	Action des rayons infra-rouges sur le soufre d'argent. (Read July 15.)	'C. R.' cxxi. 164–166; 'Ber.' xxix. (Ref.), 63–64 (Abs.)

Chemical Relations, 1895.

C. Runge and F. Paschen.	Ueber die Bestandtheile des Clèveitgases. (Read July 11.)	'Sitzungsb. Akad. Berlin,' xxxiv. 759–763; 'J. Chem. Soc.' lxx. II. 1–2 (Abs.)
W. Ramsay . .	A Possible Combination of Argon. (Aug.)	'Chem. News,' lxxii. 51; 'Beiblätter,' xix. 730 (Abs.); 'Ber.' xxviii. (Ref.), 839–840 (Abs.); 'J. Chem. Soc.' lxx. II. 20 (Abs.)
C. Bouchard . .	Sur la présence de l'argon et de l'hélium dans certaines eaux minérales. (Read Sept. 2.)	'C. R.' cxxi. 392–394: 'Beiblätter,' xix. 827 (Abs.); 'Ber.' xxviii. (Ref.), 836 (Abs.); 'Chem. News,' lxxii. 152–153; 'Proc. Phys. Soc.' xiii. 456 (Abs.); 'J. Chem. Soc.' lxx. II. 99 (Abs.)
G. Krüss and H. Krüss.	Eine neue Methode der quantitativen Spectralanalyse. (Sept.)	'Zeitschr. f. anorg. Chem.' x. 31–43; 'Beiblätter,' xx. 26 (Abs.); 'Proc. Phys. Soc.' xiv. 14 (Abs.); 'J. Chem. Soc.' lxx. II. 215 (Abs.); 'Ber.' xxix. (Ref.), 147–148 (Abs.)
J. W. Brühl . .	Spectrochemie des Stickstoffs. III.–IV. (Read Oct. 1.)	'Ber.' xxviii. 2388–2406; 'Zeitschr. f. physikal. Chem.' xvi. 193–225, 226–241, 497–511, 512–524; 'Beiblätter,' xix. 564–565 (Abs.); 'Proc. Phys. Soc.' xiii. 328–330 (Abs.); 'J. Chem. Soc.' lxviii. II. 194, 250–251 (Abs.)
H. Wilde . .	Helium and its Place in the Natural Classification of Elementary Substances. (Read Oct. 1.)	'Phil. Mag.' [5], xl. 466–471; 'J. Chem. Soc.' lxx. II. 165–166 (Abs.)
R. Möhlau and K. Uhlmann.	Zur Kenntniss der Chinazin- und Oxazinfarbstoffe. (Oct.)	'Ann. Chem. u. Pharm.' cclxxxix. 128–130; 'J. Chem. Soc.' lxx. I. 166–169 (Abs.)
B. Paulowski. .	Ueber Allofluorescein. (Read Oct. 14.)	'Ber.' xxviii. 2360–2362.
E. Schunck and L. Marchlewski.	Zur Chemie des Chlorophylls. (Oct.)	'Ann. Chem. u. Pharm.' cclxxxix. 81–107; 'J. Chem. Soc.' lxviii. I. 396–397 (Abs.)
A. Killas and W. Ramsay.	Estimation of Gases from Certain Mineral Waters. (Read Nov. 28.)	'Proc. Roy. Soc.' lix. 68–69.
A. de Gramont .	Sur l'analyse spectrale directe des composés solides, et plus spécialement des minéraux. (Nov.)	'C. R.' cxxi. 121–123; 'Bull. Soc. Chim.' [3], xiii.–xiv. 945–947; 'Ber.' xxviii. (Ref.), 1018 (Abs.)

CHEMICAL RELATIONS, 1895, 1896.

L. Troost and L. Ouvrard.	Sur l'origine de l'argon et de l'hélium dans les gaz dégagés par certaines eaux minérales. (Read Dec. 2.)	'C. R.' cxxi. 798–800; 'Chem. News,' lxxii. 309–310.
G. Krüss . .	Beziehungen zwischen Zusammensetzung und Absorptionsspectrum organischen Verbindungen. Nachtrag. (Dec.)	'Zeitschr. f. physikal, Chem.' xviii. 559–563; 'Beiblätter,' xx. 197 (Abs.); 'J. Chem. Soc.' lxx. II. 285 (Abs.)
R. F. d'Arcy and W. B. Hardy.	Note on the Oxidising Powers of Different Regions of the Spectrum in relation to the Bactericidal Action of Light and Air.	'J. Physiol.' xvii. 390–393; 'J. Chem. Soc.' lxviii. II. 57 (Abs.)
J. Stas . . .	Recherches chimiques et études spectroscopiques sur différents corps simples. (Complete works of Stas, pub. at Brussels.)	'Chem. News,' lxxii. 177–179, 188–190, 203–205, 215–216, 226–227, 239–241, 248–251, 259–261, 274–276, 301–304, 311–313, lxxiii. 5–7, 15–17, 29–31, 39–40, 51–52, 66–68, 80–81, 88–90, 113–114, 124–126, 135–137, 147–149, 159–161, 171–173, 183–184, 192–193, 204–206, 216–218, 224–225, 241–242, 249–250, 262–264.

1896.

L. Marchlewski .	Die Chemie des Chlorophylls. (Hamburg, 82 pp.) (Jan.)	'Chem. News,' lxxiii. 23 (Review).
E. Schunck and L. Marchlewski .	Contributions to the Chemistry of Chlorophyll; Phylloporphyrin and Hæmatoporphyrin: a comparison. (Read Jan. 30.)	'Proc. Roy. Soc.' lix. 233–239.
J. W. Brühl . .	Spectrochemische Untersuchung des α- und β-mesityloxidoxalsäuren Methyls und Aethyls von Claisen. (Vorläufiger Bericht.) (Feb.)	'Ann. Chem. u. Pharm.' ccxci. 137–146; 'Beiblätter,' xx. 871 (Abs.)
J. Landauer . .	Die Spectral-Analyse. (Braunschweig, 174 pp.) (Feb.)	'Chem. News,' lxxiii. 70–71 (Review).
G. Kraemer and A. Spilker.	Ueber das Cyclopentadien im Steinkohlentheer, das Indin der Fettreihe. (Read Feb. 24.)	'Ber.' xxix. 552–561.
E. Jünger and A. Klages.	Ueber Halogenderivate des Camphens und Hydrocamphens. (Feb.)	'Ber.' xxix. 544–547.
J. W. Brühl . .	Spectrochemische Untersuchung des α- und β-Formylphenylessigesters. (Vorläufiger Bericht.) (March.)	'Ann. Chem. u. Pharm.' ccxc. 217–225; 'Ber.' xxix. (Ref.), 484 (Abs.); 'Beiblätter,' xx. 871 (Abs.)

CHEMICAL RELATIONS, 1896.

F. Tiemann and R. Schmidt.	Ueber die Verbindungen der Citronellalreihe. (Read March 9.)	'Ber.' xxix. 903–926.
" "	Ueber Homolinalool. (Read March 9.)	'Ber.' xxix. 691–695.
E. Demarçay	Sur un nouvel élément contenu dans les terres rares voisines du samarium. (Read Mar. 23.)	'C. R.' cxxii. 728–730; 'Ber.' xxix. (Ref.). 379–380 (Abs.); 'J. Chem. Soc.' lxx. II. 475 (Abs.); 'Proc. Phys. Soc.' (Abs.) xiv. 226.
H. Ritthausen	Ueber Galactit aus den Samen der gelben Lupine. (Read March 23.)	'Ber.' xxix. 896–899.
B. Tollens	Ueber den Nachweis der Pentosen mittels der Phloroglucinsalzsäureabsatzmethode. (Read April 18.)	'Ber.' xxix. 1202–1209.
W. N. Hartley	The Determination of the Composition of a 'White Sou' by a Method of Spectrographic Analysis. (Read April 23.)	'J. Chem. Soc.' lxix. 842–844: 'Chem. News, lxxiii. 229 (Abs.)
E. Schunck and L. Marchlewski	Zur Chemie des Chlorophylls. (Read May 11.)	'Ber.' xxix. 1347–1352.
A. Tschirch	Zur Chemie des Chlorophylls. (Read June 22.)	'Ber.' xxix. 1766–1770.
H. Wilde	On the Spectral and other Properties of Thallium in Relation to the Genesis of the Elements. (June.)	'Chem. News,' lxxiii. 304–305; 'Beiblätter,' xxi. 633 (Abs.)
W. N. Hartley and H. Ramage.	On the Occurrence of Gallium in the Clay-iron-stone of the Cleveland District of Yorkshire. Determination of Gallium in Blast-furnace Iron from Middlesbrough. (Read Dec. 17.)	'Proc. Roy. Soc.' lx. 393–407.
O. Buss	Beiträge zur Spectralanalyse einiger toxicologisch und pharmakognostisch wichtiger Farbstoffe, mit besonderer Berücksichtigung des Ultraviolett. (Inaug. Diss.)	'Beiblätter,' xxi. 130–131 (Notice).
H. Krüss	Ueber ein neues Verfahren in der quantitativen Spectralanalyse ('Verhandl. Ges. Deutsch. Naturf. u. Aerzte,' II. 1. Hälfte, 76–77.)	'Beiblätter,' xx. [31] (title).
E. Riegler	Die Bestimmung des Alkohols und Extractes im Wein auf optischem Wege.	'Zeitschr. f. anal. Chem.' xxxv. 27–31; 'Ber.' xxix. (Ref.), 599 (Abs.)
E. Wiedemann and G. C. Schmidt.	Photochemische Zersetzung von NaCl, KCl, NaBr und KBr unter dem Einfluss von starkbrechbaren ultravioletten Lichte.	'Jahrb. f. Photogr.' x. 15.
E. Schunck and L. Marchlewski.	Zur Chemie des Chlorophylls. (IV. Abhandlung.)	'Ann. Chem. u. Pharm. ccxc. 306–313; 'Ber.' xxix. (Ref.), 415 (Abs.)

CHEMICAL RELATIONS, 1896, 1897.

A. Wroblewsky	Anwendung des Glan'schen Spectrophotometers auf die Tierchemie. I. Quantitative Bestimmung des Hämoglobins im Blute. II. Quantitative Bestimmung der Rhodansalze im Speichel ('Anz. Akad. Krakau,' 1896, pp. 306–309, 386–390).	'Chem. Centr.' 1897, ii. 532 (Abs.); 'Beiblätter,' xxi. 573 (Abs.)

1897.

W. N. Hartley and H. Ramage.	On the Dissemination of some of the Rarer Elements, and the Mode of their Association in Common Ores and Minerals. (Read Jan. 21.)	'J. Chem. Soc.' lxxi. 533–547; 'Chem. News,' lxxix. 129–130 (Abs.)
" "	On the Spectrographic Analysis of some Commercial Samples of Metals, of Chemical Preparations, and of Minerals from the Stassfurt Potash Beds. (Read Feb. 18.)	'J. Chem. Soc.' lxxi. 547–550; 'Chem. News,' lxxv. 151 (Abs.); 'Chem. Centr.' 1897, I. 665 (Abs.)
K. D. Chruschtschoff	Sur les terres de monazite. (Read March 18.)	'J. Russ. Phys. Chem. Soc.' xxix. 206–208; 'Chem. Centr.' 1897, II. 329 (Abs.); 'Nature,' lvi. 276; 'Beiblätter,' xxi. 920 (Abs.)
G. Urbain and E. Budischovsky	Recherches sur les sables monazités. (Read March 22.)	'C. R.' cxxiv. 618–621; 'Chem. News,' lxxv. 181–182.
J. W. Brühl	Spectrochemie des Stickstoffs. V. (April.)	'Zeitschr. f. physikal. Chem.' xxii. 373–409; 'J. Chem. Soc.' lxxii. II. 297 (Abs.); 'Beiblätter,' xxi. 586–588 (Abs.); 'Chem. Centr.' 1897, II. 81–83 (Abs.)
W. N. Hartley and H. Ramage.	A Spectrographic Analysis of Iron Meteorites, Siderolites, and Meteoric Stones. (Read May 19.) ('Proc. Roy. Soc. Dublin' [N.S.], viii. Part 6.)	'Nature,' lvii. 546 (Abs.); 'Chem. News,' lxxvii. 121–122.
L. Lewin	Die spectroscopische Blutuntersuchung. (June.)	'Arch. der Pharm.' ccxxxv. 245–255; 'Chem. Centr.' 1887, II. 381 (Abs.); 'J. Chem. Soc.' lxxii. II. 534 (Abs.)
B. Hasselberg	Note on the Chemical Composition of the Mineral Rutile. (June.)	'Astrophys. J.' vi. 23–26; 'Chem. News,' lxxvi. 102–104; 'Chem. Centr.' 1897, II. 712 (Abs.)
E. Knoevenagel	Untersuchungen in der hydroaromatischen Reihe. (June.)	'Ann. Chem. u. Pharm.' ccxcvii. 113–203; 'Chem. Centr.' 1897, II. 696–702 (Abs.)

R. Lespieu . .	Recherches sur les épidibromhydrines et les composés propargyliques. (June.)	'Ann. Chim. et Phys.' [7], xi. 232–288 ; 'Chem. Centr.' (1897), II. 180–183 (Abs.)
J. R. Rydberg .	The New Series in the Spectrum of Hydrogen. (Oct.)	'Astrophys. J.' vi. 233–238 ; 'Beiblätter,' xxii. 153 (Abs.).
H. Wilde . .	Sur les poids atomiques de l'argon et de l'hélium. (Nov.)	'C. R.' cxxv. 649–651 ; 'J. Chem. Soc.' lxxiv. II. 115 (Abs.)
B. Hasselberg .	Ueber das Vorkommen des Vanads in den Scandinavischen Rutilarten ('Bihang till Handl. Svensk. Vet. Akad.' xxii. I. No. 7, 7 pp.)	'Astrophys. J.' v. 194–198.
G. P. Tschernik .	Sur la nature des gaz obtenus des deux minéraux ceritiques du Caucase.	'J. Russ. Phys. Chem. Soc.' xxix. 291–302 ; 'Chem. Centr.' 1897, II. 674–675 (Abs.)
Z. Donogány . .	Die Darstellung des Hämochromogens als Blutreaction, mit besonderer Berücksichtigung des Nachweises von Blut im Harn.	'Arch. f. Anat. u. Physiol.' cxlviii. 234–243 ; 'J. Chem. Soc.' lxxii. II. 468 (Abs.)
H. Tornöe . .	Spectrometrisch - aräometrische Bieranalyse. ('Pharm. Centr.-H.' xxxviii. 871–873.)	'Chem. Centr.' 1897, I. 270–271.

IX.

THEORETICAL PAPERS.

1890.

M. Korten . .	Ueber die specifische Brechung-, Volumen- und Refractionsäquivalente von sieben aus C, H und O bestehenden Flüssigkeiten, nach den Formeln von Beer (Landolt), Lorenz, und Ketteler. (Inaug. Dissert. Bonn, 1890, 53 pp.)	'Beiblätter,' xiv. 769–772 (Abs.)

1891.

A. A. Rambaut .	On the Determination of the Orbit of a Double Star from Spectroscopic Observation of the Velocity of the Components in the Line of Sight. (March.)	'Monthly Not. Roy. Astr. Soc.' li. 316–330.

1892.

C. Runge and G. J. Stoney.	The Line Spectra of the Elements. (Letters.) (May.)	'Nature,' xlvi. 29, 100, 126, 200, 247, 268 ; 'Beiblätter,' xviii. 559–560 (Abs.)
G. J. Stoney . .	On the Line Spectra of the Elements. (July.)	'Nature,' xlvi. 268–269.

Theoretical Papers, 1892, 1893, 1894.

R. R. Tatnall . .	A New Proof of a Fundamental Equation of the Spectrometer. (Dec.)	'Astron. and Astrophys.' xi. 932–933; 'Beiblätter,' xvii. 824–825 (Abs.)

1893.

W. J. Sollas . .	The Law of Gladstone and Dale as an Optical Probe. (Read Jan. 18.)	'Proc. Roy. Soc. Dubl.' [N.S.], viii. 157–166 (Abs.); 'Beiblätter,' xviii. 995–996 (Abs.)
R. Nasini . .	Sul potere rifrangente per un raggio di lunghezza d' onda infinita. (Read Feb. 19.)	'Rend. R. Accad. d. Lincei' [5], ii. I. sem. 161–166; 'Beiblätter,' xvii. 739 (Abs.)
G. W. Colles . .	Distances of the Stars by Doppler's Principle. (April.)	'Amer. J. Sci.' [3], xlv. 259–267.
M. Aymonnet .	Sur les *maxima* périodiques des spectres. (Read Aug. 7.)	'C. R.' cxvii. 304–306, 402–405; 'Nature,' xlviii. 536 (Abs.)
M. Kuhfahl . .	Die Ablenkung des Strahles beim Prisma. (Aug.)	'Zeitschr. f. phys. u. chem. Unterr.' vi. 301.
S. Pagliani . .	Sulle equazioni della refrazione della luce. (Read Aug. 20.)	'Rend. R. Accad. d. Lincei' [5], ii. II. sem. 107–112.
H. C. Vogel . .	Ueber die Bezeichnung der Linien des I. Wasserstoffsspectrums. (Nov.)	'Astr. Nachr.' cxxxiv. 95–96; 'Nature,' xlix. 162 (Abs.)
A. Cornu . .	Vérifications numériques relatives aux propriétés focales des réseaux diffringents plans. (Read Dec. 26.)	'C. R.' cxvii. 1032–1039; 'Nature,' xlix. 239–240 (Abs.)

1894.

C. Runge . .	On a Certain Law in the Spectra of some of the Elements. (Feb.)	'Astron. and Astrophys.' xiii. 128–130.
R. Lehmann-Filhès	Ueber die Bestimmung einer Doppelsternbahn aus spectroscopischen Messungen der im Visionsradius liegenden Geschwindigkeitscomponenten. (July.)	'Astr. Nachr.' cxxxvi. 17–30.
G. Moreau . .	De la périodicité des raies d'absorption des corps isotropes. (Read Aug. 20.)	'C. R.' cxix. 422–425; 'Beiblätter,' xix. 494 (Abs.); 'Proc. Phys. Soc.' xiii. 108-110 (Abs.)
H. Rubens . .	Prüfung der Ketteler-Helmholtz'-schen Dispersionsformel. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], liii. 266–286; 'Nature,' l. 635 (Abs.); 'Naturwiss. Rundschau,' ix. 389–391.
R. Nasini . .	Coefficiente critico in relazione colla formula $\frac{n-1}{d}$. (Read Sept. 14.)	'Gazz. chim. ital.' xxiii. II. 576–587; 'J. Chem. Soc.' lxvi. II. 173–174 (Abs.)
Ph. A. Guye . .	Détermination du poids moléculaire des liquides. (Read Nov. 12.)	'C. R.' cxix. 852–854; 'J. Chem. Soc.' lviii. II. 99 (Abs.)

THEORETICAL PAPERS, 1894, 1895.

W. F. Edwards .	A New Formula for Specific and Molecular Refraction. (Dec.)	'Amer. Chem. J.' xvi. 625-634; 'J. Chem. Soc.' lxviii. II. 193 (Abs.); 'Ber.' xxviii. (Ref.), 452 (Abs.); 'Beiblätter,' xix. 420 (Abs.); 'Chem. Centralb.' 1895, i. 313-314.
G. Lippmann . .	Sur la théorie de la photographie des couleurs simples et composées par la méthode interférentielle.	'J. de Phys.' [3], iii. 97-107; 'Proc. Phys. Soc.' xiii. 63-64 (Abs.)

1895.

G. F. Fitzgerald .	On some Considerations showing that Maxwell's Theorem of Equal Partition of Energy among the Degrees of Freedom of Atoms is not inconsistent with the various Internal Movements exhibited by the Spectra of Gases. (Read Feb. 14.)	'Proc. Roy. Soc.' lvii. 312-313; 'Nature,' li. 452-453.
A. König . .	Ueber die Anzahl der unterschiedbaren Spectralfarben und Helligkeitsstufen. (Feb.)	'Zeitschr. f. Psychol. u. Physiol. d. Sinnesorgane,' viii. 375-680.
H. Rubens . .	Die Ketteler-Helmholtz'sche Dispersionsformel. (Feb.)	'Ann. Phys. u. Chem.' [N.F.], liv. 476-485; 'Proc. Phys. Soc.' xiii. 258 (Abs.)
F. Paschen . .	Dispersion und Dielectricitätsconstante. (March.)	'Ann. Phys. u. Chem.' [N.F.], liv. 668-674; 'Proc. Phys. Soc.' xiii. 284 (Abs.)
H. Poincaré . .	Sur le spectre cannelé. (Read April 8.)	'C. R.' cxx. 757-762; 'Beiblätter,' xix. 788-789 (Abs.); 'Nature,' li. 599 (Abs.)
R. Reiff . . .	Zur Dispersionstheorie. (May) .	'Ann. Phys. u. Chem.' [N.F.], lv. 82-94.
F. Zecchini . .	Sopra una nuova formola per esprimere la rifrazione specifica dei liquidi. (Read July 9.)	'Gazz. chim. ital.' xxv. II. 269-284; 'J. Chem. Soc.' lxx. II. 285 (Abs.)
B. Galitzin . .	Zur Theorie der Verbreiterung der Spectrallinien. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], lvi. 78-99; 'Nature,' lii. 611 (Abs.)
G. J. Stoney . .	On Motions competent to produce Groups of Lines which have been observed in Actual Spectra. (Read Sept. 13.)	'Brit. Assoc. Rep.' 1895, 610-612; 'Chem. News,' lxxii. 225-226; 'Beiblätter,' xx. 531, 691-692 (Abs.)

THEORETICAL PAPERS, 1895, 1896

T. F. F. See . .	Theory of the Determination by means of a Single Spectroscopic Observation of the Absolute Dimensions, Masses, and Parallaxes of the Stellar Systems whose Orbits are known from Micrometrical Measurements; with a Rigorous Method for Testing the Universality of the Law of Gravitation. (Oct.)	'Astron. and Astrophys.' xii. 812–815; 'Astr. Nachr.' cxxxix. 18–26; 'Nature,' liii. 15–16 (Abs.); 'Beiblätter,' xx. 370 (Abs.)
E. v. Lommel .	Verbreiterung der Spectrallinien. Continuirliches Spectrum. Dämpfungsconstante. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], lvi. 741–745.
A. Garbasso .	Sulla luce bianca.	'Atti d. R. Accad. d. Torino,' xxx. 186–192; 'Il Nuovo Cimento' [4], i. 305, 307 (Abs.); 'Proc. Phys. Soc.' xiii. 312 (Abs.)
H. Steigmüller .	Beziehung der Brechungsexponenten isotroper Substanzen aus Molecularformel und specifischem Gewicht derselben. (Vorläufige Mittheilung.) (Stuttgart, 1895.)	'Beiblätter,' xx. 528–529 (Abs.)
Wilsing . . .	Zur homocentrischen Brechung des Lichtes im Prisma.	'Zeitschr. f. Math. u. Phys.' xl. 353–362.

1896.

A. Belopolsky .	Spectrographische Untersuchungen über Jupiter. (Jan.)	'Astr. Nachr.' cxxxix. 209–214; 'Beiblätter,' xxi. 342 (Abs.)
J. Larmor . .	On the Absolute Minimum of Optical Deviation by a Prism. (Read Feb. 24.)	'Proc. Phil. Soc. Camb.' iv. 108–110.
E. Carvalho . .	Sur l'absorption de la lumière par les milieux doués du pouvoir rotatoire. (Read May 4.)	'C. R.' cxxii. 985–988; 'Beiblätter,' xxi. 35–36 (Abs.)
W. Wien . .	Ueber die Energievertheilung im Emissionsspectrum eines schwartzen Körpers. (July.)	'Ann. Phys. u. Chem.' [N.F.], lviii. 662–669.
C. G. Abbott and F. E. Fowle.	The Longitudinal Aberration of a Prism. (Oct.)	'Amer. J. Sci.' [4], ii. 255–257; 'Beiblätter,' xxi. 407 (Abs.)
L. Rummel . .	Spectra of the Alkalies. (Read Nov. 12.) ('Roy. Soc. Victoria,' 1896, 260–263.)	'Beiblätter,' xxi. 937 (Abs.)
J. Traube . .	Lichtbrechung und Dichte. XV. (Read Nov. 23.)	'Ber.' xxix. 2732–2742; 'Beiblätter,' xxi. 509–510 (Abs.)
H. Steigmüller .	Beziehung der Brechungsexponenten organischer Flüssigkeiten aus Molecularformel und specifischem Gewicht derselben. (Stuttgart, 1896, 24 pp.)	'Beiblätter,' xxi. 28 (Abs.)

THEORETICAL PAPERS, 1897.

P. Lugol	Minimum de déviation dans le prisme.	'J. de Phys.' [3], vi. 21–23
A. S. Herschel	The Rydberg-Schuster Law of Elementary Spectra. (Jan.)	'Nature,' lv. 271.
J. Traube	Ueber die Atomrefractionen von Kohlenstoff, Wasserstoff, Sauerstoff, Stickstoff und den Halogenen. XVI. XVII. (Read Jan. 11.)	'Ber.' xxx. 38–47; 'Beiblätter,' xxi. 510–511 (Abs.)
J. Larmor	The Influence of a Magnetic Field on Radiation Frequency. (Read Feb. 11.)	'Proc. Roy. Soc.' lx. 514–515.
G. F. Fitzgerald	Note on a Cause for the Shift of Spectral Lines. (March.)	'Astrophys. J.' v. 210–211.
A. Anderson	On the Maximum Deviation of a Ray of Light by a Prism. (Read May 25.)	'Proc. Phil. Soc. Camb.' ix. 195–197; 'Beiblätter,' xxi. 406–407 (Abs.)
H. Poincaré	La théorie de Lorentz et les expériences de Zeeman. (June.)	'Eclairage Electrique,' xiii. 481–489.
J. J. Balmer	Eine neue Formel für Spectralwellen. (Read June 7.) ('Verhandl. Naturforsch.-Gesellsch. Basel,' 1897, Heft 3, 448–463.)	'Ann. Phys. u. Chem.' [N.F.], lx. 380–391; 'Nature,' lv. 137–138; 'Astrophys. J.' v. 199–209.
L. Rummel	On the Spectra of the Alkalies and their Atomic Weights. (Read June 10.) ('Roy. Soc. Victoria,' 1897, 75–78.)	'Beiblätter,' xxi. 973 (Abs.)
F. L. O. Wadsworth	Ueber das Auflösungsvermögen von Fernröhren und Spectroscopen für Linen von endlicher Breite. (June.)	'Ann. Phys. u. Chem.' [N.F.], lxi. 604–620.
A. Garbasso	Sul modo di interpretare certe esperienze del Signor P. Zeeman di Leida. (July.)	'Il Nuovo Cimento' vi. 8–14; 'Eclairage Electrique,' xiii. 276–277.
T. M. Thiele	On the Law of Spectral Series. (Aug.)	'Astrophys. J.' vi. 65–76.
H. Becquerel	Sur une interprétation applicable au phénomène de Faraday et au phénomène de Zeeman. (Read Nov. 8.)	'C. R.' cxxv. 679; 'J. de Phys.' [3], vi. 681–688.
J. Larmor	On the Theory of the Magnetic Influence on Spectra, and on the Radiation from Moving Ions. (Dec.)	'Phil. Mag.' [5], xliv. 503–513.
A. Garbasso and G. Garbasso.	Sur la forme de la perturbation dans un rayon de lumière solaire ('Arch. de Genève' (1897), iii. 105–113).	'Beiblätter,' xxi. 123 (title).

List of the Chief Abbreviations used in the above Catalogue.

Abbreviated Title.	Full Title.
Amer. J. Sci.	American Journal of Science (Silliman's).
Ann. Agron.	Annales Agronomiques.
Ann. Chem. u. Pharm.	Annalen der Chemie und Pharmacie (Liebig).
Ann. Chim et Phys.	Annales de Chimie et de Physique.
Ann. de Chim.	Annales de Chimie.
Ann. Obs. Bruxelles	Annuaire de l'Observatoire de Bruxelles.
Ann. Phys. u. Chem. [N.F.]	Annalen der Physik und Chemie [Neue Folge] (Wiedemann).
Arch. de Genève	Archives des Sciences Physiques et Naturelles (Genève).
Arch. f. Anat. u. Physiol.	Archiv für pathologische Anatomie und Physiologie und für klinische Medicin (Virchow).
Arch. f. d. gesammte Physiol.	Archiv für die gesammte Physiologie (Pflüger).
Arch. f. exper. Pathol. u. Pharmakol.	Archiv für experimentelle Pathologie und Pharmakologie.
Arch. néerland.	Archives néerlandaises des Sciences exactes et naturelles (Haarlem).
Astr. Nachr.	Astronomische Nachrichten.
Astrophys. J.	The Astrophysical Journal (Chicago).
Atti d. R. Accad. d. Lincei	Atti della Reale Accademia dei Lincei.
Beiblätter	Beiblätter zu der Annalen der Physik und Chemie (Wiedemann).
Ber.	Berichte der deutschen chemischen Gesellschaft.
Bied. Centr.	Biedermann's Centralblatt für Agriculturchemie.
Bot. Zeitung	Botanische Zeitung.
Bull. Astron.	Bulletin Astronomique (Observatoire de Paris).
Bull. Soc. Chim.	Bulletin de la Société Chimique de Paris.
Bull. Soc. Min. de France	Bulletin de la Société Minéralogique de France.
Bull. Acad. Belg.	Bulletin de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique.
Chem. Centr.	Chemisches Centralblatt.
C. R.	Comptes Rendus de l'Académie des Sciences (Paris).
Denkschr. Akad. Wien.	Denkschriften der Akademie der Wissenschaften in Wien (Mathematisch-naturwissenschaftliche Classe).
Dingl. J.	Dingler's polytechnisches Journal.
Gazz. chim. ital.	Gazzetta chimica italiana.
Göttingen. Nachr.	Nachrichten von der Georg-August-Universität und der königl. Gesellschaft der Wissenschaften (Göttingen).
Handl. Svensk. Vet. Akad.	Handlingar K. Svenska Vetenskaps Akademiens (Stockholm).
Jahrb. f. Photogr.	Jahrbuch für Photographie (Eder).
J. Chem. Soc.	Journal of the Chemical Society of London.
J. de Phys.	Journal de Physique.
J. Physiol.	Journal of Physiology.
J. prakt. Chem.	Journal für praktische Chemie.
J. Russ. Phys.-Chem. Soc.	Journal of the Russian Physico-Chemical Society (in Russian).
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
J. Soc. franç. de Phys.	Journal de la Société française de Physique.
Math. u. naturwiss. Ber. aus Ungarn.	Mathematische und naturwissenschaftliche Berichte aus Ungarn.
Mem. spettr. ital.	Memorie della Società degli spettroscopisti italiani.
Monatsb. Akad. Berl.	Monatsberichte der Akademie der Wissenschaften zu Berlin.
Monatsh. f. Chem.	Monatshefte für Chemie (Wien).
Month. Not. R.A.S.	Monthly Notices of the Royal Astronomical Society of London.
Oefvers. af K. Vet. Akad. Förh.	Oefversigt af K. Svenska Vetenskaps Akademiens Förhandlingar.

List of the Chief Abbreviations—continued.

Abbreviated Title.	Full Title.
Phil. Mag. . . .	London, Edinburgh, and Dublin Philosophical Magazine.
Phil. Trans. . . .	Philosophical Transactions of the Royal Society of London.
Phot. Mittheil. . .	Photographische Mittheilungen (Vogel).
Phys. Review . . .	Physical Review.
Phys. Revue . . .	Physikalische Revue.
Proc. Phys. Soc. . .	Proceedings of the Physical Society of London.
Proc. Roy. Inst. . .	Proceedings of the Royal Institution of Great Britain.
Proc. Roy. Soc. . .	Proceedings of the Royal Society of London.
Rec. des. trav. chim. des Pays-Bas.	Recueil des travaux chimiques des Pays-Bas.
Rend. R. Accad. d. Lincei	Rendiconti della Reale Accademia dei Lincei.
Riv. sci. industr. . .	Rivista scientifico-industriale.
Sitzungsb. Akad. Berl. .	Sitzungsberichte der Akademie der Wissenschaften zu Berlin.
Sitzungsb. Akad. München	Sitzungsberichte der königlich baierischen Akademie zu München.
Sitzungsb. Akad. Wien .	Sitzungsberichte der Akademie der Wissenschaften zu Wien.
Sitzungsb. phys.-med. Soc. Erlangen.	Sitzungsberichte der phys.-medicinischen Societät zu Erlangen.
Skand. Arch. f. Physiol. .	Skandinavisches Archiv für Physiologie (Leipzig).
Verh. phys. Gesellsch. Berlin.	Verhandlungen der physikalischen Gesellschaft zu Berlin.
Wien. Anz. . . .	Anzeiger der k. Akademie der Wissenschaften zu Wien.
Zeitschr. f. anal. Chem. .	Zeitschrift für analytische Chemie.
Zeitschr. f. anorg. Chem. .	Zeitschrift für anorganische Chemie.
Zeitschr. f. Kryst. u. Min.	Zeitschrift für Krystallographie und Mineralogie.
Zeitschr. f. physikal. Chem.	Zeitschrift für physikalische Chemie.
Zeitschr. f. phys. u. chem. Unterr.	Zeitschrift für physikalischen und chemischen Unterricht.
Zeitschr. f. physiol. Chem.	Zeitschrift für physiologische Chemie.
Zeitschr. f. wiss. Microscopie.	Zeitschrift für wissenschaftliche Microscopie.

The Fossil Phyllopoda of the Palæozoic Rocks.—Fourteenth Report of the Committee, consisting of Professor T. WILTSHIRE (*Chairman*), Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*). (*Drawn up by* Professor T. RUPERT JONES.)

CONTENTS.

§ I. IN our First Report on the Palæozoic Phyllopoda (presented to the Association in 1883) the genus *Dithyrocaris* was included in the Tabular List at page 216 of the Reports for 1883 (1884), as being 'ridged along the back (like *Apus*),' and as 'being ridged and sometimes prickled.' It was referred to as occurring in Carboniferous and Devonian strata.

In the Fifth Report (made in 1887), at page 63–66, we enumerated all the known and reputed species of the genus. Thanks to the obliging courtesy of friends and correspondents, we are now enabled to state that we can distinguish the following species found in the British Islands and elsewhere :—

	—	Scotland	Ireland	England	Belgium	Germany	Canada	U.S. America
	Carboniferous.							
Carapaces.	1. Dithyrocaris glabra, *H. Woodward & R. Etheridge, Jun.*	*						
	2. ,, ovalis, *W. & E.*	*						
	3. ,, granulata, *W. & E.*	*						
	4. ,, testudinea, *Scouler*	*		*				
	5. ,, Scouleri, *M'Coy*	*	*					
	6. ,, funiculata, *sp. nov.*	*	*					
	7. ,, Colei, *Portlock*	*	*					
	8. ,, tricornis, *Scouler*	*		*				
	9. ,, orbicularis, *Portlock*		*					
	10. ,, tenuistriata, *M'Coy*		*	*	*			
	11. ,, Youngii, *sp. nov.*	*						
	12. ,, striata, *Woodward*	*						
Tail-pieces.	13. ,, lateralis, *M'Coy*	*		*				
	14. ,, Neilsoni, *sp. nov.*	*						
	15. ,, Dunnii, *sp. nov.*	*		*				
	16. ,, carbonaria, *Meek & Worthen*							*
	17. Rhachura venosa, *Scudder*							*
	Devonian.							
Cara-pace	18. Dithyrocaris Belli, *Woodward*						*	
Tail-pieces.	19. ,, Kochi, *Ludwig*					*		
	20. ,, breviaculeata, *Ludwig*					*		
	21. ,, (?) Jaschei, *Römer*					*		
	22. ,, Kayseri, *Clarke*					*		
	23. Mesothyra Oceani, *Hall & Clarke*							*
	24. ,, Neptuni, *Hall.*							*
	Carboniferous.							
	Mandibles or Gastric Teeth	*	*	*				

Dithyrocaris has a clypeiform test; at all events most of the specimens have a shield-like test, readily dividing into two moieties or valves; but some specimens seem to support the idea of having been able to fold the two sides together. The moieties are often separate, and some are too convex to have formed a quite flat shield; some have the lateral edges turned sharply downwards and inwards.

The valves, or two lateral moieties, were united along their dorsal edges simply; several specimens, however, had a dorsal rugose ridge-plate, over-riding, narrow, and longitudinal (somewhat like that described as an intervening plate in *Mesothyra* by Hall and Clarke in 1888), ending in a posterior spine.

The valves are sub-oblong, straight along the middle two-thirds of the dorsal border, and elliptically curved ventrally; more or less rounded at the ends, with a median hollow or notch at their junction on the front and hind borders. The antero-dorsal region ends with a blunt angle or a short process; and the postero-ventral with a strong, sharp, trigonal spine.

The straight hinge-line is defined by two small dorsal notches. The ventral border has a striated, serrated, or fringed margin, either on its posterior moiety or throughout its extent.

The surface of each valve bears one longitudinal (*meso-lateral*) ridge, and sometimes others parallel; also short ridges (*cephalic*) over the gastric apparatus, and slighter ridges (*nuchal*) near the top of the dorsal ridge, all more or less rugose.

Scattered granulations and tubercles are often present on some parts of the valves, also lines and reticulations.

Granulation is feeble and sparse on *D. glabra* and *D. ovalis*; strong and abundant on *D. granulata.* Small prickles, rising from the meshes of a reticulation, are scattered over *D. tricornis, D. Colei,* and *D. orbicularis* (?). A system of oblique transverse lines characterises *D. testudinea.* A feeble reticulation is traceable on *D. funiculata* and *D. Scouleri* (?). Longitudinal striæ mark the surface in *D. Belli* and *D. striata*; and *D. tenuistriata* and *D. Youngii* have longitudinal costulæ.

In consideration of certain differences in the carapaces, we separate Nos. 10 and 11 of the Table, at page 2, from *Dithyrocaris*, as *Chænocaris tenuistriata* and *Ch. Youngii*, the carapace being bivalved and *gaping*. There is also an obscure Devonian form, from Saalfeld, to which we refer as *Chænocaris Richteriana.* We regard No. 12 as having a *closed* bivalved test, and therefore designate it as *Calyptocaris striata.*

We have had the opportunity of studying an old Apus-like fossil labelled 'Burdiehouse.' It shows a small circular carapace (measuring 15 by 13 mm.), with strong postero-ventral angles, and distinct meso-lateral ridges leading to them; also a slightly curved depression in the middle of the front border, and a granulated margin throughout.

Mr. E. J. Garwood, F.G.S., who is a member of the British Association Committee for defining the zones in the Carboniferous rocks, has just now forwarded for our examination a very interesting collection of the remains of *Dithyrocaris* from excavations in the shales of the Millstone-grit series at Eccup, Yorkshire.

§ II. In the 'Proceed. United States National Museum,' vol. xix. 1897, Mr. C. Schuchert has a paper 'On the Fossil Phyllopod Genera *Dipeltis* [Packard *emend.*] and *Protocaris.*' The latter was noticed in our Report to the Association for 1889, p. 64, and in our Ninth Report (for 1891), p. 300. The original genus *Dipeltis* was established by A. S. Packard, in the 'Memoirs of the National Academy of Sciences,' vol. iii. 1885, Mem. xvi. p. 145, pl. v. figs. 2, 2*a*, as one of the Carboniferous Xiphosura of North America. In the December number of 'Natural Science,' 1897 (vol. xi. p. 401, figs. 2–5), in his paper on 'Fossil Apodidæ,' Mr. H. M. Bernard follows Mr. Schuchert in regarding the Dipeltis, as defined by the latter, as a Phyllopodous Apus-larva. Mr. C. J. Gahan, however, in 'Natural Science,' January 1898, pp. 42–44, points out that it is really a larval form of the Blattarian Insect *Etoblattina*, described and figured by H. Woodward in the 'Geological Magazine,' 1887, p. 433, pl. xii.

§ III. With reference to the Bohemian *Estheriæ* mentioned at page 4 of our Report for 1893 (Tenth, 1894), Dr. Anton Fritsch has informed us that they were named by him in the 'Sitzungsb. k. böhm. Gesellsch. Wissen.' 1894: No. 1 being *Estheria triangularis*, Fr.; No. 2, *E. cyenea*, Fr.; No. 3 [and No. 4 ?], *E. palæoniscorum*, Fr.; and No. 5, *E. calcarea.*

Canadian Pleistocene Flora and Fauna: Report of the Committee, consisting of Sir J. W. DAWSON (*Chairman*), Professor D. P. PENHALLOW, Dr. H. AMI, Mr. G. W. LAMPLUGH *and* Professor A. P. COLEMAN (*Secretary*), *appointed to further investigate the Flora and Fauna of the Pleistocene Beds in Canada.*

THE most extensive and interesting series of inter-glacial beds in Canada, if not in America, occurs in and near Toronto, along the valley of the Don and at Scarborough Heights. The beds at Scarborough were admirably described by George Jennings Hinde in 1878,[1] but no further attention was paid to the inter-glacial deposits of the region until 1894, when a paper on fossils obtained from the Don Valley was published by A. P. Coleman.[2] In the following year the same geologist made an attempt to correlate the Don and Scarborough series of deposits, which, though only a few miles apart, present very different features, the fossil remains from Scarborough indicating a climate cooler than the present, while the fossils from the Don suggest a decidedly warmer climate than that now found at Toronto.[3] At the Toronto meeting of this Association a paper adding new points to those previously published was read before the Geological Section by A. P. Coleman, and the two most important localities were visited by members of the Section; with the result that a grant of 20*l.* was made, to be used in investigating the flora and fauna of the Pleistocene of the region.

In expending the grant two points were kept specially in view—the finding of new fossils, particularly wood and leaves, so as to determine as certainly as possible the climatic conditions at the time when the beds were deposited; and the determination of the relations between the cold-climate beds (peaty clays) of Scarborough and the warm-climate beds (unio sands and clays) of the Don Valley.

Important results have been obtained in both directions.

Excavations made at Gaol Hill, in the Don Valley, have provided a considerable amount of wood and a portion of the head of a large fish, while collections made at the Don Valley brickworks have added numerous leaves to the flora previously known.

Specimens of wood were obtained also from the Scarborough clays and sands, as well as from similar beds at Price's brickyard, half-way between Scarborough and the Don. All the plant remains have been determined by Professor Penhallow, and are described by him in an appendix to this report.

The peaty clays (cold-climate beds) and the unio sands and clays (warm-climate beds) had never been found with absolute certainty in the same section, and in order to determine their relative position three wells or shafts were sunk—two at the foot of Scarborough Heights, half a mile east of Victoria Park, and one at Price's brickyard.

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[1] 'Glacial and Inter-glacial Strata of Scarborough Heights,' *Can. Jour.*, 1878, p. 388, &c.

[2] *American Geologist*, vol. xiii., Feb. 1894, pp. 85–95.

[3] *Journal of Geology*, vol. iii., No. 6, 1895, pp. 622–645.

The Scarborough wells were dug on the shore of Lake Ontario, beneath the cliff; but on account of the delay of the well-diggers the first one was not started till the middle of November, and, owing to stormy weather during the latter part of November and the first week of December, it had reached only 20 feet below the level of the lake when waves began to break in and the well had to be abandoned. The section disclosed 3 feet of bluish stratified clay with peaty layers and a thin sheet of clay ironstone, closely resembling the overlying peaty clay which rises about 90 feet above the lake. Below this, blue clay without peat, but having some thin layers of coarse gray sand interbedded, extended about 18 feet below the lake, when a foot or two of dark reddish clay with sandy layers occurred. No fossils of any kind were obtained except a small amount of peat near the surface.

The second well was sunk at Price's brickyard, four or five miles northeast of the first one, nearly a mile north of Lake Ontario, and about 30 feet above the lake level. This well reached a depth of 21 feet 9 inches, when a stratum of water-bearing sand was encountered and the well quickly filled. With the powerful flow of water came quantities of combustible gas. The section displayed practically the same features found in the Scarborough well, but a little wood was found at a depth of 10 feet below the surface, or 20 feet above Lake Ontario. Numerous rounded pebbles were obtained in the clay, a point of difference from the overlying peaty clay, which rarely contains pebbles.

The third well was sunk at the foot of the Scarborough cliff, not far from the first, during the fine weather of the latter part of May of the present year. This last attempt proved much the most successful of the three, though not all that was hoped for was accomplished, since the Hudson River strata underlying the whole region were not reached. At the depth of 44 feet water-bearing sand was reached, and the well filled to the level of the adjoining lake.

Fifteen feet below the lake level somewhat sandy layers of clay were found to contain two species of Sphaerium, and in one case also a Unio shell, unfortunately too badly preserved to be determined. From this to the bottom, 41 feet below the lake, fragments of shells and pieces of wood were sparingly obtained. The lower sandy layers of clay from this well are reddish, and correspond closely in appearance to the beds disclosed in the excavation of Gaol Hill, near the Don, where wood and leaves of warm-climate trees had been obtained. From this fact, and the additional facts that coarse sand and unios have never been found in the Scarborough peaty clay beds, there seems no doubt that the third well passed out of the peaty clay into the unio sands and clays characteristic of the warm-climate beds. It may be looked on as proved that the deposits containing fossils indicative of a warm climate underlie conformably the peaty clays charged with leaves, &c., proving a cold climate.

Another item of information obtained during the winter confirms the conclusion reached above. Professor Goldwin Smith has been good enough to give details of a well sunk some years ago at The Grange, in the southern part of Toronto, where, after passing through 30 feet of tough clay, a bed of sand was reached furnishing a great flow of water. The well-diggers found a small log of wood in this sand.

A similar find is reported by an old well-digger from a well on Wilton Avenue, between The Grange and the river Don.

We may conclude that sands containing wood and unios like those found along the Don Valley extend widely beneath the clays of the region, and that the warm-climate beds underlie the cold-climate beds conformably. As the Don beds rest upon a layer of boulder clay, and the cold-climate beds are covered by another layer of boulder clay, both are clearly inter-glacial.

Professor Chamberlin, of Chicago University, has suggested the name 'Toronto formation' for these fossiliferous deposits, and thinks that they probably occupy the interval between the Iowan and Wisconsin till sheets, and are a possible equivalent of Dr. James Geikie's Neudeckian, in the Old World.[1]

Starting from a level more than 40 feet below the surface of Lake Ontario, the following section is found at Scarborough:—

	Feet
6. Complex till with inter-bedded stratified sand and clay . .	200
Great interval of erosion.	
5. Stratified sand with shells and trees of a cold climate . .	55
4. Peaty clays with plants and beetles of a cold climate . .	95
3. Clays and sands with unios and trees of a warm climate . .	35
2. A lowest till of variable thickness	—
1. Eroded surface of Hudson River (Cambro-silurian) shales .	—

During the past year the area known to be covered by the unio beds and the peaty clays has been greatly extended. The former have been shown to stretch seven miles from east to west and a mile and a half from north to south, indicating an area of ten square miles and possibly very much more. The peaty clay has been followed seventeen miles from east to west and six miles to the north of Lake Ontario. It probably covers at least 100 square miles of territory. The two series, together with the overlying inter-glacial fossiliferous sands, are more than 185 feet in thickness at Scarborough.

We may look on the Toronto formation as representing a great delta deposit in a lake extending some miles farther north than Lake Ontario does at Toronto at present. At first this great inter-glacial lake stood about 80 feet higher than the present water-level, and the climate was like that of Ohio or Pennsylvania. The lake then deepened till its surface stood at least 150 feet above the present Lake Ontario, and the climate altered to one like that of Southern Labrador.

We must suppose that these immense beds of clay and sand were not deposited by feeble streams like the present Don and Humber, but probably by an inter-glacial successor of Dr. Spencer's pre-glacial 'Laurentian river,' draining the upper Great Lakes directly from the Georgian Bay, instead of through the present circuitous route by Lake Erie and Niagara. Even with so powerful a river the formation of these massive inter-glacial beds must have required a great length of time.

After they were laid down the inter-glacial predecessor of Lake Ontario was drained below its present level long enough to allow various small streams to erode wide valleys through the strata just referred to, since the second till sheet fills in two or three such valleys, as shown at the Scarborough escarpment. The time required for these erosive operations must have been long, perhaps as long as the time since the final retreat of the ice from the region of Toronto; and the whole length of time demanded for this inter-glacial period cannot be less than five or ten thousand years.

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[1] *Journal of Geology*, vol. iii., No. 3, pp. 273–275.

Lists of the fossils found at Scarborough and in the Don Valley up to the past year have been published in the papers previously referred to in this report, while additional species of plants found during the year are detailed in the appendix, so that it will be unnecessary to give lists in full of the fossils of the Toronto formation. The following summary will serve to give a general idea of the fauna and flora of the two divisions of the formation :—

Fossils of the Don Valley Beds.

Fauna.—Unios, 10 species and a variety ; three not now found in Canada. Other lamellibranchs, 5 species. Gasteropods, 20 species ; making 35 molluscs. Cyprids (undetermined), at least one species. Fish (undetermined), one species. Beetles (undetermined), a few species.

Flora.—Trees, 35 species ; several not now found as far north as Toronto, one extinct. Grasses, only one determined. Mosses (undetermined), several species. Chara, one species ; making in all more than 70 species of plants and animals.

Fossils of the Cold-climate Beds.

Fauna.—Lamellibranchs, 2 species. Gasteropods, 3 species. Beetles, 56 species determined by Dr. Scudder, with others not yet worked out.[1] Horn of Rangifer caribou.

Flora.—Trees, 6 species. Shrubs, 2 species. Mosses, probably 10 species. Chara, 1 species. Diatoms, 3 species ; in all 22 species of plants, making a total of 84 species of plants and animals. Omitting species common to both sets of deposits, the whole number of plants and animals found in the Toronto formation exceeds 140.

Careful search has been made for remains of *Apus glacialis* in material from the peaty clays, Mr. Bennie having been good enough to send excellent slides of mounted specimens for comparison, but hitherto none has been found. It is probable that the climate during the formation of the Scarborough beds, though decidedly cooler than that of Toronto at present, was not Arctic in character, so that *Apus glacialis* could hardly be expected to occur. It is intended to search some of the stratified clay and sand interbedded with boulder clay in the complex of the middle till of the region, which must have been laid down under Arctic conditions.

APPENDIX.

Pleistocene Flora of the Don Valley.—By D. P. PENHALLOW.

Investigations of the Pleistocene flora for the past year, conducted under the patronage of the British Association, have been confined almost exclusively to the deposits in the vicinity of Toronto, where special explorations have been made under the immediate supervision of Prof. A. P. Coleman. The material obtained has been of two kinds : (*a*) fragments of wood in various stages of preservation, and (*b*) leaves and fruits. It has served not only to confirm previous conclusions as to the character

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[1] Contributions to *Can. Pal.*, vol. ii., part 1, Insects. Twenty-five species, all extinct, found by Dr. Hinde at Scarborough, are here described and figured. The others have not yet been published.

of the vegetation and climate of the Don period, but it has extended our knowledge of the flora in important directions.

(*a*) *Fragments of Wood.*—With few exceptions the wood occurs in fragments—either mere splinters or pieces of branches—and they show not only more or less extended decay, but the external appearance indicates the rather prolonged action of water. This appears in the rounded and worn surfaces and angles, and suggests that the material may have been transported for some distance by river, or that it was thrown upon a beach and then subjected to the prolonged action of waves. In no case has the silicification of the structure been carried very far. All the woods so far studied cut readily with a saw, they soften with ease in boiling water—in a few cases only requiring the addition of sodium carbonate—and the sections are subsequently cut on an ordinary microtome. Alterations due to the extreme effect of decay and subsequent pressure are common, but in most cases have been of such a nature as to permit a recognition of the genus.

While in many cases decay has progressed so far as to make the genus or species recognisable with difficulty—sometimes not at all—in other cases the same species may be preserved with remarkable perfection, so that all the features of the internal structure may be distinguished as in a piece of wood freshly cut from a living tree. In one case (*Juniperus virginiana*) the preservation was so perfect that the original colour of the wood was suggested by the external appearance; a radial fracture showed the characteristic aspect of the medullary rays; the shredded bark was recognisable, and, when cut with a saw, a perceptible odour of cedar was noticed. External characters are rarely preserved to such an extent; but one other case (*Maclura aurantiaca*) merits notice, in that the presence of perfectly preserved spines—in some cases half-buried in an overgrowth of wood—served abundantly to confirm previous conclusions drawn from the internal structure alone. In nearly all the Pleistocene woods thus far brought under observation it has been found that in those cases in which decay has not been carried to an extreme the various species acquire certain well-defined external characters whereby it is possible to distinguish them without microscopic examination. The species studied during the year are as follows, and from the localities indicated:[1]—

Taylor's Brickyard, Don Valley.

Platanus occidentalis, *Linn.*
Maclura aurantiaca, *Nutt.*
Larix americana, *Michx.*
*Juniperus virginiana, *Linn.*

Price's Brickyard, Don Valley.

Larix americana, *Michx.*
*Pinus strobus (?), *Linn.*

Gaol Hill, Don Valley.

*Juniperus virginiana, *Linn.*
Maclura aurantiaca, *Nutt.*
*Quercus rubra (?), *Linn.*
*Quercus alba (?), *Linn.*

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[1] The * denotes, in this and the succeeding pages, species additional to those of the previous list, the † that they are new to the locality.

Scarborough Heights.

†Larix americana.

Of these, five are additional to the species previously reported, while one is new (*Larix americana*) to the deposits of the Don Valley.

(*b*) *Leaves and Fruits.*—In 1894–5 Mr. Townsend collected a large amount of material from Taylor's brickyard, which was subsequently deposited in the Museum of the Geological Survey at Ottawa, and during the past winter was placed in my hands for study. All of this material was extremely friable, as the matrix consisted of clay. It was, therefore, necessary to carefully size it before detailed study could be made. For the benefit of future collectors it may be pointed out that where leaves are found in soft clay, and are therefore represented almost entirely by mere impressions, the finer details of the venation—an essential element in the determinations—do not appear until after the material has been sized. This should be done by immersion of the specimen in fish glue or alcoholic shellac, sufficiently thin to permit of thorough penetration. The shellac is to be preferred, not only because of the greater ease with which it penetrates the matrix, but because of the fact that no damage will result if the specimen accidentally comes in contact with water.

The greater part of this material proved to be new, and it thus gave a direct and important addition to previous lists. Very rarely, however, were the leaves at all perfectly preserved. The specimens were fragments only, and but few cases exhibited even the margin. Determinations, therefore, had to be based chiefly upon the character of the venation. It will thus be seen that such determinations must of necessity be subject to a certain element of error, particularly in cases like *Ulmus*, *Fagus*, *Carpinus*, *Ostrya*, &c., where the venation is closely similar; but by very careful comparison with leaves recently collected, and a critical study of the direction, average interval and branching of the veins, it is believed the error from this source has been reduced to a minimum. However, in all cases where there seems to be reason to believe a doubt exists the name is followed by a query—a rule which applies to all species throughout the list.

More recently Professor Coleman has placed in my hands a smaller collection of leaves from the same locality. While many are specifically identical with those of the Townsend collection, others are new, and thus still further extend the list. The following are the species found, with their localities:—

Taylor's Brickyard.

Acer pleistocenicum, *Penh.*
*Acer spicatum, *Lam.*
*Cratægus tomentosa, *Linn.* Var. punctata, *Gray.*
*Carya alba, *Nutt.*
*Eriocaulon septangulare (?), *With.*
*Festuca ovina (?), *Linn.* Spike.
*Fraxinus americana (?), *Linn.*
*Fraxinus sambucifolia, *Lam.*
†Populus balsamifera (?), *Linn.*
†Populus grandidentata, *Michx.*

*Prunus sp. Stone of fruit.
*Potamogeton natans, *Linn.*
*Quercus acuminata, *Roxb.*
*Quercus discolor, *Ait.*
*Quercus macrocarpa (?), *Michx.*
Salix sp.
Sedge and grass leaves.
*Tilea americana, *Linn.*
Ulmus americana, *Linn.* Fruit and leaves.
*Robinia pseudacacia, *Linn.*

Gaol Hill.

*Carya alba, *Nutt.*
*Festuca ovina (?), *Linn.* Spike.
†Hypnum sp.
Grasses and mosses in fragments.
*Tilea americana, *Linn.* Leaves and fruit.
*Robinia pseudacacia, *Linn*
Ulmus americana, *Linn.*

A feature of special interest in the leaf specimens is to be found in the recurrence of very good specimens of *Acer pleistocenicum.* When this leaf was obtained from the Don some years since, the one imperfect specimen led to the belief that a new species had been found. Other and somewhat more perfect specimens from these later collections prove the correctness of the original diagnosis, and show that the species as a new one must stand.

From these general results it appears that our previous list has been extended by a total of eighteen new species, giving a total of eighty-one species now known, while three species occur in new localities.

Of the species the identity of which is to some extent in doubt, and which require more ample material for final conclusions, it may be observed that *Fraxinus quadrangulata* of an earlier list, represented by wood only, may be *F. sambucifolia.* Similarly, *Quercus rubra* and *Q. alba*, represented by wood only, may be *Q. discolor* and *Q. macrocarpa* respectively, these last being represented by leaves. So long, however, as there is a reasonable probability that these various species occur, so far as may be gathered from the characteristic features of the specimens, they must stand in the list provisionally, their validity being determined by future examinations of additional material.

Turning to the extent of the flora represented by the material studied up to the present time, I find the whole number of species for the various deposits examined to be as follows :—

		Compared with Don, Identical species.
Don Valley	35	0
Green's Creek and Besserer's	21	2
Scarborough Heights	14	2
Montreal	6	3
Moose River	5	2

The Don deposits contain four species which also occur in one or more of the other localities.

Considering the evidence of climatic conditions afforded by these plants, I find in the first place that the evidence which indicated that during the Don period a much warmer climate prevailed than in any of the other localities is greatly strengthened. If, then, we consider the Pleistocene flora as evidence of climate in comparison with the climate of the present day, the following results appear:—

Per cent. of species compatible with as warm or a warmer climate	44·4 +
Per cent. of species indicative of a warmer climate. . . .	27·7 +
Per cent. of species compatible with as cool or a cooler climate	24·07
Per cent. of species indicative of a colder climate . . .	3·7 +

It would thus appear that while a very few northern types found their southern limit of distribution at this point, the great majority of the plants—72 per cent.—were such as belong essentially to warmer regions, 28 per cent. being particularly indicative of a greater degree of warmth than now prevails in the same region.

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. Marr (*Chairman*), Mr. E. J. Garwood (*Secretary*), *and* Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Dr. Wheelton Hind, Dr. G. J. Hinde, Mr. P. F. Kendall, Mr. J. W. Kirkley, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. G. H. Morton, Professor H. A. Nicholson, Mr. B. N. Peach, Mr. A. Strahan, *and* Dr. H. Woodward, *appointed for the purpose of studying the Life-zones in the Carboniferous Rocks. (Drawn up by the Secretary.)*

Since the last meeting of the Association the collection authorised by the Committee to be made from the deposit of the Millstone Grit Age at Eccup has reached the Secretary, and has been distributed among the palæontologists specially appointed by the Committee. Full reports from these have not yet come to hand; but the collection is rich both in species and individuals, and is probably one of the most valuable that has been made from the Millstone Grit.

Considerable difficulty has been met with in the housing and treatment of the large collection already received; and this has materially hindered the progress of the work for which the Committee were appointed. But they are now glad to announce that the Director-General of the Geological Survey, hearing of this difficulty and appreciating the great value of the collection, very kindly, not only offered accommodation for the collections of the Committee in the Museum of the Geological Survey in Jermyn Street, but promised every facility for the study of the specimens by the specialists appointed by the Committee.

In consequence of the difficulties mentioned above the Committee felt it impossible to encourage individual workers to make collections from the other beds of the series until some definite resolution should be come to with regard to the housing of the specimens. They are, however, glad to notice that since attention has been drawn to the importance of zoning the Carboniferous rocks in Britain several papers have appeared which they hope are only the forerunners of numerous interesting communications on the same subject.

The Committee beg to renew their application for a small grant for working expenses, which have already exceeded the amount originally voted to them, the expenses, entailed by carriage of specimens, being a constantly recurring charge on the Secretary of the Committee.

Photographs of Geological Interest in the United Kingdom.—Ninth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Mr. J. E. BEDFORD, Mr. H. COATES, Mr. C. V. CROOK, Mr. E. J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. H. TIDDEMAN, Mr. H. B. WOODWARD, Mr. F. WOOLNOUGH, *and* Professor W. W. WATTS (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee have the honour to report that during the year 250 new photographs have been received, bringing the total number in the collection up to 2,001. No circulars have been sent out this year, but, in spite of this, the number is above the average.

In addition to this 44 prints and 14 slides have been given to the duplicate collection, which now contains many representative photographs, so that future additions are likely not to be so numerous, and to consist only of exceptionally good examples of geological phenomena.

The usual detailed list is appended in a shortened form, and a glance at it will show that Northampton is now represented for the first time in the collection, and that the following counties and districts are more richly represented than hitherto :—Gloucester, Norfolk, Warwick, Westmoreland, Worcester, the Isle of Man, Aberdeen, Ayr, Bute, Banff, Fife, Inverness, and Sutherland.

Amongst the more noteworthy donations may be mentioned an interesting set from Arran, Cumbrae, Ailsa Craig, and the Fifeshire volcanic necks by Mr. A. S. Reid, together with some from Westmoreland and Banffshire by the same donor ; a set from Glenroy and the Scottish Highlands by Mr. W. Lamond Howie ; large series from Westmoreland and Yorkshire, many of them representing glacial phenomena, unconformities, and faults, by Mr. Godfrey Bingley ; pleistocene deposits by Mr. G. Nichols ; dykes in the new red sandstone by the North Staffordshire Naturalists' Field Club ; silurian, cambrian, and igneous rocks of the Midlands by Mr. K. F. Bishop ; raised beaches in Devon by Miss Partridge ; oolites by Mr. Coomara-Swamy ; a set from the Rochdale district by the Rochdale Literary and Scientific Society ; a set from the Isle of Man ; and one of typical specimens of rocks and microscopic slides. To the donors mentioned and to the following your Committee are especially indebted :—Mr. H. Preston, Mr. H. A. Allen, Mr. S. S. Platt, Mr. A. Strahan, Mr. Lowe, Mr. Stebbing, Mr. Hingley, Miss Andrews, Mr. Meigh, Mr. Turner, Mr. H. C. McNeill, Mr. C. E. Salmon, Miss M. C. Crosfield, and to Herr Björlykke.

The Committee would call attention to the small amount of work yet done in such districts as N. and S. Wales, the Yorkshire Dales and Moors, the Malverns, the districts round Oxford and Cambridge, Cornwall, the Southern Uplands, the Central Valley of Scotland, and Central and Southern Ireland.

—	Previous collection	New additions (1898)	Total	Duplicates			
				Previous collection	Additions (1898)		Total
					Prints	Slides	
England—							
Cheshire . .	48	—	48	11	—	1	12
Cumberland .	6	2	8	—	—	—	—
Devon . .	89	6	95	6	2	—	8
Dorset . .	51	1	52	6	—	—	6
Gloucester .	6	6	12	1	—	—	1
Kent . .	58	2	60	9	4	—	13
Lancashire .	41	8	49	10	—	—	10
Leicester .	91	—	91	19	—	1	20
Monmouth .	4	1	5	1	1	—	2
Norfolk . .	10	6	16	5	2	—	7
Northampton .	—	6	6	—	—	—	—
Shropshire .	26	2	28	8	—	—	8
Somerset. .	39	—	39	8	1	—	9
Stafford . .	26	8	34	6	—	—	6
Suffolk . .	2	2	4	—	—	—	—
Surrey . .	17	4	21	3	—	—	3
Warwick . .	11	7	18	1	—	—	1
Westmoreland.	10	46	56	—	6	—	6
Worcester .	2	3	5	1	—	—	1
Yorkshire .	321	42	363	58	2	—	60
Others . .	169	—	169	7	—	—	7
Total . .	1027	152	1179	160	18	2	180
Wales—							
Carnarvon .	62	—	62	23	—	1	24
Denbigh . .	13	—	13	1	4	—	5
Glamorgan .	12	—	12	2	1	—	3
Merioneth .	19	1	20	2	1	2	5
Others . .	16	—	16	6	—	—	6
Total . .	122	1	123	34	6	3	43
Isle of Man .	30	22	52	3	—	1	4
Scotland—							
Aberdeen .	2	6	8	—	—	—	—
Argyll . .	26	2	28	1	—	—	1
Ayr . . .	1	5	6	1	4	—	5
Banff . .	1	3	4	—	—	—	—
Bute . .	1	5	6	—	—	—	—
Fife . .	7	7	14	7	—	—	7
Inverness .		14	38	—	1	—	1
Lanark . .	4	1	5	5	—	—	5
Perth . .	15	4	19	3	—	—	3
Sutherland .	3	3	6	2	—	—	2
Others . .	82	—	82	24	—	—	24
Total . .	166	50	216	43	5	—	48

—	Previous collection	New additions (1898)	Total	Duplicates			
				Previous collection	Additions (1898)		Total
					Prints	Slides	
IRELAND—							
Antrim . .	164	1	165	25	1	—	26
Galway . .	23	1	24	3	—	—	3
Others . .	165	—	155	23	—	—	23
Total . .	342	2	344	51	1	—	52
ROCK STRUCTURES. .	50	23	73	8	14	6	28
ENGLAND .	1027	152	1179	160	18	2	180
WALES . .	122	1	123	34	6	3	43
CHANNEL ISLANDS .	14	—	14	—	—	—	—
ISLE OF MAN .	30	22	52	3	—	1	4
SCOTLAND .	166	50	216	43	5	—	48
IRELAND . .	342	2	344	51	1	—	52
ROCK STRUCTURES. .	50	23	73	8	14	6	28
Others . .	—	—	—	1	—	2	3
Total . .	1751	250	2001	300	44	14	358

The Committee note with pleasure that one of their most valued contributors has placed many of his negatives in the hands of a dealer, from whom lantern-slides may be obtained. If this example were often followed it would be an easier matter for those who wish to obtain copies of photographs to do so without taxing the good nature of contributors. The Secretary often has to deal with requests from British and foreign geologists who want prints or slides from the photographs placed on these lists.

Notices of the work of the Committee have appeared in many periodicals and journals, including 'Science Gossip,' 'The Practical Photographer,' and 'The Standard,' while 'Nature' published an account of last year's collection, accompanied by processed reproductions of photographs kindly lent for the purpose by Mr. R. McF. Mure, Mr. Godfrey Bingley, and Mr. R. Welch.

Series of photographs contributed by the North Staffordshire Naturalists' Field Club, the Rochdale Literary and Scientific Society, and the Hull Geological Society, indicate that local societies continue to take a friendly interest in the work, and that in addition to collecting photographs for themselves in their own district, they are willing to help forward the national collection.

The most important event of the year, from a photographic point of view, is the inauguration of the National Photographic Record Association, under the presidency of Sir J. B. Stone, M.P. The work of this Association is distinct from that of this Committee, as it is mainly limited to *records*, while the Committee aim at securing *typical phenomena* as well as records. The Committee will furnish to the Association each year a list of the photographs of which the Association ought, where possible, to secure duplicates. The Secretary has been elected a member of Council of the Association.

The photographs received during the year are now being mounted, and, after exhibition at Bristol, will be bound up with the rest of the collection at the Museum of Practical Geology, 28 Jermyn Street, where they may always be referred to on application to the Librarian. The entire collection is arranged topographically under counties and their natural divisions, so that reference is as easy as circumstances will permit. A catalogue arranged under counties is kept at Jermyn Street, and a card catalogue is maintained up to date as new photographs are received.

Mention was made in the Report for 1897 of the formation of a duplicate loan collection of prints and slides. This has now been arranged geologically and made available for circulation. The additions made during the year—forty-four prints and fourteen slides—are acknowledged in List II. A descriptive account of the slides has been printed by the Secretary, and sent to those societies which have borrowed them for exhibition. This description has also proved useful as labels for such prints as deal with subjects similar to the slides.

The duplicate collection has been lent to the Dublin Field Club, the Belfast Field Club, the Birmingham Natural History and Philosophical Society, and to the Photographic Exhibition at the Crystal Palace. Applications for the loan of this collection for the forthcoming winter should be made to the Secretary as soon as possible. The only expense to the borrowing Societies is the carriage (one way only when that can be arranged) and the making good of any damage to prints or slides.

A list of donors to this collection is appended to List II., and to them the Committee express their thanks.

The photographs in this selected series are naturally of the kind which would be most useful to those who wish to obtain typical examples for teaching purposes or for exhibition in illustration of papers; and therefore, whenever it has been possible to arrange it, an address is given whence prints or slides may be purchased. But it must be distinctly understood that the Committee can undertake no responsibility or correspondence in this matter. All information possible will be circulated with the collection, and there the Committee's work must end; would-be purchasers must make their own arrangements with photographers, in whom exclusively the copyright remains vested.

It has been decided to discontinue issuing the list of *published photographs*, as no important service appears to be rendered by it, but a careful record will be kept of all photographs which have been used to illustrate papers or books. The Committee are indebted to the editors of the 'Quarterly Journal of the Geological Society' and of the 'Proceedings of the Geologists Association' for help rendered in connexion with this branch of the work.

The Secretary will be grateful if the donors of photographs will kindly look through the parts of the lists in which they are interested and will notify to him any slips in the spelling of proper names, in the geographical or geological descriptions, or mistakes of any other kind which occur in the Report.

The Committee ask for their reappointment with a small grant to defray some of the expenses connected with the mounting, storing, and collection of the photographs, and for printing such circulars and forms as are necessary for carrying on the work.

NINTH LIST OF GEOLOGICAL PHOTOGRAPHS

(TO JUNE 30, 1898).

NOTE.—This list contains the subjects of geological photographs copies of which have been received by the Secretary of the Committee since the publication of the last Report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers, where given, are added, in the same order, to enable them to do so.

Copies of photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the Local Society under whose auspices the views were taken.

The price at which copies may be obtained depends on the size of the print and on local circumstances, over which the Committee have no control.

The Committee find it necessary to reiterate the fact that they *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should *not* be addressed to the Committee, but to the photographers direct.

The very best photographs lose half their utility, and all their value as documentary evidence, unless accurately described; and the Secretary would be grateful if, wherever possible, such explanatory details as can be given were written on the forms supplied for the purpose, and *not on the back of the photograph or elsewhere.* Much labour and error of transcription would thereby be saved. A local number by which the print can be recognised should be written on the back of the photograph and on the top right-hand corner of the form.

Copies of photographs should be sent *unmounted* to W. W. Watts, Mason University College, Birmingham, and forms may be obtained from him.

The size of photographs is indicated as follows:—

L = Lantern size.
1/4 = Quarter-plate.
1/2 = Half-plate.
1/1 = Whole plate.
10/8 = 10 inches by 8.
12/10 = 12 inches by 10, &c.

E signifies Enlargements.

* indicates that photographs and slides may be purchased from the donors, or the address given with the series.

LIST I.

ENGLAND.

CUMBERLAND.—*Photographed by* A. S. REID, *Trinity College, Glenalmond, N.B.* 1/4.

Regd. No.			
1792	(M 78) Watendlath Tarn from North.	Moraine-dammed tarn.	1895.
1793	(M 81) Watendlath Tarn from North.	,, ,, ,,	,,

DEVONSHIRE.—*Photographed by* MISS E. M. PARTRIDGE, 75 *High Street, Barnstaple.* 1/2.

Regd. No.		
1884	(1) Saunton Down End, Barnstaple Bay.	Crumpled Pilton Beds. 1897.
1885	(2) Saunton Down End, Barnstaple Bay.	Raised Beach on Pilton Beds. 1897.
1886	(3) Saunton Down End, Barnstaple Bay.	„ „ „ „
1887	(4) Saunton Down End, Barnstaple Bay.	„ „ „ „
1943	(5) Saunton Down End, Barnstaple Bay.	Pseudo-ripple marking in Pilton Beds. 1898.
1942	(6) Saunton . . .	Contorted Pilton Beds. 1898.

DORSET.—*Photographed by* H. PRESTON, *Grantham.* 1/4.

2007	( ) Eypemouth, near Bridport .	Bathonian faulted against Middle Lias. 1898.

GLOUCESTER.—*Photographed by* A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/4 and (E.).

1959	(g 4) Quarry on top of Cleeve Hill	'Harford Sands,' covered by a little 'Snowshill Clay,' Inferior Oolite. 1897.
1960	(g 5) Cleeve Hill . . .	Escarpment of Pisolite. 1897.
1961	(g 6) „ „ . . .	„ „ „
1962	(g 7) „ „ . . .	„ „ „
1963	(g 9) Leckhampton Hill (E.) .	Succession of Inferior Oolite. 1897.
1964	(g 13) Minchinhampton, large quarry (E.).	False Bedding in Great Oolite. 1897.

KENT.—*Photographed by* H. A. ALLEN, 28 *Jermyn Street, London, S.W.* 1/4.

1888	( ) Crayford, Brick Pit . .	Thanet Sand on Chalk. 1897.
1889	( ) Camden Park Pit, Chislehurst.	Thanet Sand resting on Chalk. 1897.

LANCASHIRE.—*Photographed by* F. GREENWOOD, 5 *St. Mary's Gate, Rochdale.** *Presented by the* ROCHDALE LIT. AND SC. SOCIETY. 1/2.

2009	(167) Littleborough, Rochdale .	Slickensided Millstone Grit. 1897.
2010	(168) Leach Hill, Blackstone Edge, near Rochdale.	Jointed Millstone Grit and talus of fragments broken along joints. 1897.
2011	(169) Tom Stones, Blackstone Edge Moor, near Rochdale.	Weathering of Millstone Grit. 1897.
2012	(170) Nicholas Pike, E. by N. of Rochdale.	Glacial Boulder of Buttermere Granophyre, 1,050 feet above O. D. 1897.

Photographed by A. S. REID, *Trinity College, Glenalmond, N.B.* 1/4.

1869	(G 16) Hampsfell, near Grange .	'Grikes' in Carboniferous Limestone. 1893.
1870	(G 17) „ „ .	„ „ „
1871	(G 20) „ „ .	„ „ „
1872	(G 21) „ „ .	„ „ „

MONMOUTHSHIRE.—*Photographed by* H. L. P. LOWE, *Shirenewton Hall, Chepstow.* 1/2.

1804	( ) Severn Tunnel Cutting . .	Water-bearing stratum with frozen springs.

NORFOLK.—*Photographed by* A. STRAHAN, 28 *Jermyn Street, London, S.W.* 1/4.

Regd. No.		
1786	(68) Half-a-mile west of Cromer	Contorted Drift. 1893.
1787	(41) West of Cromer	Boulder 40 feet long in Contorted Drift. 1893.
1788	(32) Near Trimingham	*Leda myalis* Bed, Forest Bed and Contorted Drift. 1893.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

1893	(4218) Mundesley	Cliffs of Sand. 1897.
1894	(4219) „	Sands with Clay at base. 1897.
1895	(4220) „	Sands on Chalk. 1897.

NORTHAMPTON.—*Photographed by* G. NICHOLS, *The Drapery, Northampton.* 1/2.

1874	(3) Mr. Martin's Brickyard, Northampton.	Section of Clay. 1897.
1875	(4) Mr. Martin's Brickyard, Northampton.	Trees in Clay. 1897.
1876	(5) Mr. Martin's Brickyard, Northampton.	„ „ „
1877	(2) Mr. Martin's Brickyard, Northampton.	Skulls of *Bos taurus.* 1897.
1878	(1) Mr. Martin's Brickyard, Northampton.	„ „ „
1890	(6) Mr. Martin's Brickyard, Northampton.	Trunk of oak, 32 feet, by 4 feet 6 inches. 1898.

SHROPSHIRE.—*Photographed by* K. F. BISHOP, 18 *New Street, West Bromwich.* 1/4.

1944	( ) The Longmynd, near Plowden.	Llandovery Rocks resting unconformably on Longmyndian Rocks. 1898.
1945	( ) The Longmynd, near Plowden.	Bedding and Cleavage in Longmyndian Rocks. 1898.

STAFFORDSHIRE.—*Photographed by* A. MEIGH, *Ash Hall, Stoke-on-Trent. Contributed by the* NORTH STAFFORDSHIRE FIELD CLUB. 1/2.

1879	(1) Quarry near Butterton Church, Trentham.	Basalt Dyke in Permian Rocks. 1892.
1880	(2) Hanchurch Hills	Basalt Dyke, piercing Bunter Pebble Beds. 1892.
1881	(3) Gravel Pit, Trentham Park	Bunter Pebble Beds and Sandstone. 1892.
1882	(4) „ „ „	Current bedding in Sands and Pebble Beds of the Bunter. 1892.

Photographed by H. M. S. TURNER, *Hanley. Contributed by the* NORTH STAFFORDSHIRE FIELD CUB. 1/2.

1883	(5) Coombes Valley, Cheddleton, near Leek.	Contorted Yoredale Shales. 1893.

Photographed by K. F. BISHOP, 18 *New Street, West Bromwich.* 1/4.

1946	( ) Rowley Regis	Starch-like columns in Dolerite. 1898.
1947	( ) Quarry ¼-mile N.E. of Oldham House, Rowley.	Columnar Dolerite. 1898.
1948	( ) Quarry at Turner's Hill, near Rowley.	Relation of jointing to Spheroidal Structure. 1898.

SUFFOLK.—*Photographed by* W. D. HARMER, *St. Bartholomew's Hospital, London.* 1/2.

Regd. No.		
2005	(1) Iken, near Aldeburgh . .	Coralline Crag.
2006	(2) „ „ . .	„ „

SURREY.—*Photographed by* W. P. D. STEBBING, 169 *Gloucester Terrace, Hyde Park, London, W.* 1/4.

1831	(A) Betchworth	Granite boulder in Chalk, 7 lbs. 7 ozs. 1896.
1832	(B) „	Granite boulder in Chalk, 3 lbs. 12 ozs. 1896.

Photographed by C. E. SALMON, *Clevelands, Reigate.* 1/2.

1891	(1) Colley Hill Quarry, Reigate .	Chloritic Marl and Upper Greensand. 1897.
1892	(2) Frenches Pit, Red Hill. .	Folkestone Sand covered by Drift. 1897.

WARWICKSHIRE.—*Photographed by* W. W. WATTS, *Mason University College, Birmingham.* 1/4.

1949	(372) Quarry near Midland Station, Nuneaton.	Cambrian Quartzite, overlain by Trias. 1898.
1950	(365) Mr. Trye's Quarry, N. of Nuneaton.	Diorite Dyke intrusive in Cambrian Quartzite. 1898.
1951	(364) Mr. Trye's Quarry, N. of Nuneaton.	Diorite Dyke intrusive in Cambrian Quartzite. 1898.
1952	(370) Camp Hill Grange Quarry, near Nuneaton.	*Hyolithus* Beds of the Cambrian. 1898.
1953	(369) Camp Hill Grange Quarry, near Nuneaton.	„ „ „ „
1954	(366) Old Quarry, near Chapel End, Nuneaton.	Dyke of Diorite repeated three times by faults. 1898.
1955	(367) Mr. Trye's Railway Cutting, Chapel End.	Stockingford Shales overlain unconformably by Carboniferous Beds. 1898.

WESTMORELAND.—*Photographed by* A. S. REID, *Trinity College, Glenalmond, N.B.* 1/4.

1789	(M 58) Murton Pike . . .	Fault separating Carboniferous Limestone from Skiddaw Slate. 1895.
1790	(M 59) Mell Fell and Roman Fell.	Skiddaw Slate and Carboniferous Limestone. 1895.
1791	(M 39) Head of Scordale . .	Great Whin Sill and Carboniferous Limestone. 1895.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

Lantern slides from those marked thus (*) may be obtained from Messrs. Reynolds & Branson, Commercial Street, Leeds.

1896*	(4452) Augill Beck, Brough-under-Stainmoor.	Lower Carboniferous Sandstone. 1898.
1897	(4453) „ „ „	„ „ „ „
1898	(4455) „ „ „	„ „ „ „
1899	(4457) „ „ „	„ „ „ „
1900*	(4458) „ „ „	Vertical Lower Carboniferous Sandstone. 1898.
1901*	(4459) „ „ „	„ „ „ „
1902*	(4428) Shap Quarries, Wasdale Crag.	Granite. 1898.

Regd. No.			
1903	(4431)	Shap Quarries, Wasdale Crag.	Granite. 1898.
1904*	(4432)	" " "	Segregation patches in Granite. 1898.
1905*	(4433)	" " "	Roches moutonnées of Granite. 1898.
1906*	(4426)	Wasdale Crag, side of Railway.	Glacial striæ on Granite. 1898.
1907*	(4434)	Wasdale Beck, near Shap Wells.	Basement Carboniferous Conglomerate with pebbles of Shap Granite. 1898.
1908*	(4420)	High Cup Nick, near Appleby.	Whin Sill in Carboniferous Limestone 1898.
1909*	(4415)	" " "	" " " "
1910*	(4418)	" " "	" " " "
1911*	(4416)	" " "	" " " "
1912*	(4417)	" " "	" " " "
1913*	(4360)	Hoff Beck, near Appleby.	Carboniferous Limestone Escarpment. 1898.
1914*	(4361)	" "	" " "
1915	(4362)	" "	Lower Brockram Escarpment. 1898.
1916*	(4363)	" "	" " " "
1917*	(4364)	" "	" " joints passing through pebbles. 1898.
1918*	(4366)	" "	" " " "
1919	(4370)	Hunrigg's Quarry, near Appleby.	Lower Brockram. 1898
1920*	(4371)	Hilton Beck, Appleby. .	Penrith Sandstone (Permian). 1898.
1921*	(4374)	" "	Upper Brockram Escarpment. 1898.
1922*	(4375)	Hilton Quarry, near Appleby.	St. Bee's Sandstone. 1898.
1923	(4378)	Hilton Beck, near Hilton.	View across the Pennine Fault. 1898.
1924*	(4395)	Dufton Pike and Brownber.	Middle Pennine Fault. 1898.
1925	(4444)	" " "	Inner and Middle Pennine Faults. 1898.
1926*	(4411)	Murton Pike . . .	Inner Pennine Fault. 1898.
1927*	(4421)	Middle Tongue, High Cup Gill.	" " " Moraines. 1898.
1928	(4396)	Brownber from near Knock Pike.	" " " 1898.
1929*	(4410)	From near Harbour Flat, Appleby.	" " " Moraines. 1898.
1930*	(4408)	Inner Tongue from Harbour Flat, Appleby.	Terminal Moraines. 1898.
1931	(4409)	Near Harbour Flat, Appleby.	Moraine Mounds. 1898.
1932*	(4419)	Murton Pike . . .	Moraines. 1898.
1933	(4391)	Dufton Pike and Cosca Moraines.	" "
1934	(4381)	Looking up Hilton Beck from Roman Fell.	" "
1935	(4379)	Hilton Beck, near Hilton.	Position of Dufton Shales. 1898.
1936	(4407)	From Brackenthwaite, near Appleby.	Cross Fell Inlier. 1898.
1937	(4399)	Knock Pike . . .	" " " "
1938	(4393)	Dufton Pike and Swindale Beck.	" " " "

WORCESTERSHIRE.—*Photographed by* K. F. BISHOP, 18 *New Street, West Bromwich.* 1/4.

1956	( )	Wren's Nest, Dudley .	Jointing and Cavern in Wenlock Limestone. 1898.
1957	( )	" " " .	Curve in strike of Wenlock Limestone. 1898.
1958	( )	" " " .	Overfold in Wenlock Limestone. 1898.

YORKSHIRE.—*Photographed by* G. HINGLEY, *The School House, Cullercoats.* 1/2.

Regd. No.		
1833	( ) The Buttertubs Pass between Wensleydale and Swaledale.	Swallow-hole in Carboniferous Limestone. 1897.
1834	( ) „ „ „	„ „ „ „

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

1965	(4517) Crummack Dale, near Clapham.	Glaciated Silurian Rocks. 1898.
1966	(4515) „ „ „	Basement of Carboniferous Limestone. 1898.
1967	(4519) Crummack Beck Head .	Junction of Carboniferous Limestone and Silurian Rocks. 1898.
1968	(4520) „ „ „ .	Basement Beds of Silurian resting on Ordovician, and both covered unconformably by Carboniferous Limestone. 1898.
1969	(4514) Crummack Dale . .	Face of Silurian Rocks from which the Norber Boulders were carried. 1898.
1970	(4516) „ „ . .	Line of Norber Boulders. 1898.
1971	(4509) Norber Brow, near Clapham.	Erratic Boulders of Silurian Rocks perched on pedestals of Carboniferous Limestone. 1898.
1972	(4508) „ „ „ „	Pedestal striated. 1898.
1973	(4503) „ „ „ „	Terminal Moraine of Norber Glacier. 1898.
1974	(4506) „ „ „ „	„ „ „ „ „
1975	(4493) Gaping Gill and Fell Beck, Ingleborough.	Swallow-hole in Carboniferous Limestone. 1898.
1976	(4425) „ „ „	„ „ „
1977	(4496) „ „ „	Stream Course in Carboniferous Limestone. 1898.
1978	(4498) Below Gaping Gill, Fell Beck, Ingleborough.	Old Swallow-hole in Carboniferous Limestone. 1898.
1979	(4484) Skirwirth Quarries, Ingleton.	Carboniferous Limestone. 1898.
1980	(4487) 'Granite' Quarries, Ingleton.	Ancient (pre-Silurian) Grit. 1898.
1981	(4488) „ „ „	„ „ „ „
1982	(4492) Ingleborough, from top of Raven Scar.	Carboniferous Limestone capped by Millstone Grit. 1898.
1983	(4490) Raven Scar, Ingleton .	Terrace of Carboniferous Limestone. 1898.
1984	(4485) Under Raven Scar, Ingleton.	Unconformable Junction of Carboniferous Limestone on Ancient (pre-Silurian) Rocks. 1898.
1985	(4486) „ „ „ „	Carboniferous Limestone resting unconformably on upturned Ancient (pre-Silurian) Rocks. 1898.

Photographed by J. T. DYSON, *Hopwood Street, Hull. Contributed by the* HULL GEOLOGICAL SOCIETY. 1/2.

1986	(1) Kettleness, South of Runswick Bay.	Junction of Middle and Upper Lias. 1894.
1987	(2) Blea Wyke Nab . . .	Junction of Lias and Oolite. 1894.
1988	(3) „ „ „	„ „ „ „
1989	(4) „ „ „	*Nerinæa* band in Dogger. 1894.
1993	(8) North Ferriby Cliff, River Humber.	Boulder Clay overlain by Clay of Hessle type. 1896.

Regd. No.			
1994	(9)	North Ferriby Cliff, River Humber.	Lower Boulder Clay overlain by warps. 1896.
1995	(10)	" " " "	" " " "
1996	(11)	" " " "	'Intermediate Bed.'

Photographed by E. H. HOWLETT, *Wright Street, Hull. Contributed by the* HULL GEOLOGICAL SOCIETY. 1/2.

1990	(5)	Southfield, Hessle . .	Hessle Gravel, under Boulder Clay. 1895.
1991	(6)	Chalk Lane, Hull . .	'Forest Bed.' 1894.
1992	(7)	" " " . .	" " "

Photographed by H. PERCY, *High Street, Doncaster.* 1/2.

1997	(12)	Bempton, Flamborough .	Chalk Cliff. 1895.
1998	(15)	Thornwick Bay, Flamborough.	Bedded Chalk. 1895.
1999	(17)	North Landing, Flamborough.	Cave in bedded Chalk. 1895.
2000	(18)	King and Queen Rocks, Flamborough.	Stacks of Chalk. 1895.
2001	(23)	Flamborough Head . .	Denudation of Chalk. 1895.
2002	(26)	Warmsworth, nr. Doncaster.	Magnesian Limestone. 1898. 1/1.
2003	(27)	Wadworth, near Doncaster.	Anticline in Magnesian Limestone. 1898.
2004	(28)	Balby, near Doncaster .	Sand-pit. 1898.

WALES.

MERIONETH.—*Photographed by* W. W. WATTS, *Mason University College, Birmingham.* 1/4.

1856 (336) Harlech, railway cutting. Boulder Clay. 1895.

ISLE OF MAN.

Photographed by W. W. WATTS, *Mason University College, Birmingham.* 1/4.

1764	(M 1)	Langness, near Castletown.	Broken dyke in Manx Slates. 1897.
1765	(M 2)	" "	Tertiary dyke in Carboniferous Conglomerate. 1897.
1767	(M 5)	" "	" " " "
1766	(M 3)	" "	Basement Carboniferous Conglomerate. 1897.
1768	(M 6)	" "	Unconformity of Carboniferous on Manx Slates. 1897.
1769	(M 7)	" "	" "
1770	(M 8)	" "	" "
1771	(M 12)	" " (The Arches)	" "
1772	(M 16)	Langness, near Castletown.	Dyke in Carboniferous Conglomerate. 1897.
1773	(M 18)	Glen Wyllin .	River Terraces. 1897.
1774	(M 20)	Ballaheigh	Dry Valley. 1897.
1775	(M 21)	" .	" " continuation of.
1776	(M 22)	Bishop's Glen . .	" looking up.
1777	(M 37)	Lamb Hill, Bride Hills .	" " " down.
1778	(M 38)	" " .	" " " up.
1779	(M 39)	Ballavarkish, " .	" " " down.
1780	(M 40)	" " .	" " " up.

Regd. No.			
1781	(M 43)	Shore at E. end of Bride Hills, near Ramsey.	Sand cemented into dyke-like masses, and 'scrablag.' 1897.
1782 to **1785**	(M 31 to M 34)	Panorama of the Bride Hills from the South.	Drift, Boulder Loam, and Gravel with dry valleys. 1897.

Photographed by E. NEWALL. 1/1.
Transferred to new number on account of duplication.

887	( )	Shore near Stack of Scarlett, Castletown.	Carboniferous Limestone.

SCOTLAND.

ABERDEEN.—*Photographed by* W. LAMOND HOWIE, *Monton Lodge, Eccles.* 1/4.

1806	( )	Lochnagar from Cioch Mhor.	Panorama.
1807	( )	From the Great Corrie, Lochnagar.	„
1808	( )	Ben Muich Dhui from Loch Etchachan.	„ 1892.
1809	( )	Cairn Toul and Loch an Uaine.	„ „
1810	( )	View from Ben Muich Dhui.	„
1826	( )	Ben Muich Dhui . .	Summer snow. 1893.

ARGYLL.—*Photographed by* W. LAMOND HOWIE, *Monton Lodge, Eccles.* 1/4.

1811	( )	East ridge of Ben Cruachan from Glen Strae.	Panorama.
1827	( )	Ben Cruachan . . .	Disintegration of Granite. 1893.

AYRSHIRE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 1/4.

1799	(M 18)	Ailsa Craig, from N.W. .	General character of Island. 1895.
1800	(M 20)	„ „	Columnar Microgranite. 1895.
1801	(M 21)	„ „	Columnar structure and dykes. 1895.
1802	(M 30)	Biglees Burn . . .	Undercut Waterfall in Old Red Sandstone Conglomerate. 1895. (E.)
1803	(M 32)	Glen Biglees . . .	„ „ „ „ „ (E.)

BANFFSHIRE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 1/2.

1828	(HP 115)	Troup, W. of Cullycan.	Blow-hole fallen in. 1897.
1829	(HP 116)	„ „	„ „ „
1830	(HP 113)	„ „	„ „ „

BUTE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 1/4.

1794	(M 4)	Arran, Corriegills Shore .	Basic dyke. 1895.
1795	(M 3)	„ „ „	Pitchstone dyke. 1895.
1796	(M 5)	„ „ „	Boulder of Granite (?) 1895.
1797	(M 7)	Great Cumbrae . .	Lion dyke from South. 1895.
1798	(M 12)	„ „ . .	„ „ „ „ „

FIFESHIRE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 6/4.

Regd. No.			
1858	(HP 164)	East of Newark Castle.	White trap dyke in black Shales. 1897.
1859	(HP 161)	West of Ardross Castle, near Elie.	Agglomerate of 'neck.' 1897.
1860	(HP 189)	Beneath Ardross Castle.	Bedding and jointing of Calciferous Sandstone. 1897.
1861	(HP 163)	„ „ „	Faulted ripple-marks in Sandstone. 1897.
1862	(HP 175)	Between Pittenweems and St. Monans.	Dip and strike in Calciferous Sandstones, Shales, &c. 1897.
1863	(HP 181)	Kincraig Point, W. of Elie.	Remains of volcanic 'neck.' 1897.
1864	(HP 172)	„ „ „	Dyke of curvi-columnar Basalt in 'neck.' 1897.

INVERNESS-SHIRE.—*Photographed by* W. LAMOND HOWIE, *Monton Lodge, Eccles.* 1/4 *and* 5/4.

1812	( )	Glenroy, looking N. . .	'Parallel Roads.' 1895.
1813	( )	„ „	„ „ „
1814	( )	Glenroy	„ „ „
1815	( )	„	„ „ „
1816	( )	„ East Leana Mhor from West Leana Mhor.	„ „ „
1817	( )	„ „ „ „	„ „ „ two.
1818	( )	Glenroy	„ „ „ near view of one
1819	( )	Glen adjacent to Glenroy, down Glen Collary.	Two 'parallel roads.' 1895.
1820	( )	Loch Coire an Lochan, Braeriach.	Panorama. 1896.
1821	( )	„ „ „	„ „
1822	( )	Braeriach, 3,250 . .	Snow in summer. 1896.
1823	( )	„ „ . .	„ „ „ crevassed.
1824	( )	Below Loch Eunach, Cairngorms.	River terraces. 1894.
1825	( )	Loch Eunach and Sgurr an Dhu, Cairngorms.	Moraine mounds. 1894.

LANARK.—**Photographed by* R. McF. MURE, 35 *Underwood, Paisley.* 1/2.

2013*	( )	Partick, near Glasgow .	Fossil Coal-measure Forest.

PERTHSHIRE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 6/4.

1865	(HP 75)	The 'Deil's puttin' stane,' Callander.	Perched Block. 1897
1866	(HP 77)	„ „ „ „	„ „ „
1867	(HP 80)	Loch Lubnaig, from above Strathyre.	Delta of Balvag River. 1897.
1868	(HP 81)	„ „ „	„ „ „ „

SUTHERLANDSHIRE.—*Photographed by* K. O. BJÖRLYKKE, *Norges Geologiske undersogelse, Kristiania.* 1/2.

1939	( )	Near Inchnadamff . .	Thrust-plane by roadside. 1897.
1940	( )	North side Glencoul. .	Glencoul thrust-plane. 1897.
1941	( )	South side Glencoul. .	„ „ „

IRELAND.

ANTRIM.—*Photographed by* Miss M. K. ANDREWS, *College Gardens, Belfast.* 10/8. (E.)

Regd. No.		
1873	(2) Quarry near Templepatrick	Chalk, Rhyolite, and Basalt. 1895.

Replaced by Dr. TEMPEST ANDERSON, *Stonegate, York.* 1/1.

568	( ) Portmoon	Marine denudation.

CLARE.—*Photographed by* W. H. F. ALEXANDER. 1/4.
Transferred to new number on account of duplication.

547	Kilkee	Marine denudation; caves and headlands.
548	,,	,, ,, ,, ,,
549	,,	,, ,, ,, ,,

GALWAY.—*Photographed by* H. L. P. LOWE, *Shirenewton Hall, Chepstow.* 1/2.

1805	( ) Between Lough Fin and Lough Muck.	Glaciation.

ROCK-STRUCTURES, &c.

Photographed by W. W. WATTS, *Mason University College, Birmingham.* 1/4. 1897.

1835	(309)	Boulder, Hordwell Cliff, Hants.	Conglomerate.
1836	(251)	Selsea, Sussex	Flint Breccia.
1837	(310)	Flintshire	Crinoidal Carboniferous Limestone.
1838	(281)	Dudley, Staffs	Wenlock Limestone.
1839	(290)	Nailsworth, Glos.	Oolitic Limestone. Inferior Oolite. (M.)
1840	(299)	Moira, Leicester	Spore Coal (M.) Transverse section.
1841	(300)	,, ,,	,, ,, ,, Longitudinal.
1842	(264)	Doncaster, York	Glaciated Boulder.
1843	(268)	Banffshire	Contorted Mica-schist.
1844	(284)	Scotland	Contorted Slate. (M.)
1845	(307)	Little Caradoc, Salop	Quartzite. (M.)
1846	(313)	Rhiconich, Aberdeenshire	Hornblendic Gneiss.
1847	(272)	Antrim	Amygdaloidal Basalt.
1848	(282)	Tardree, Antrim	Rhyolite, with flow-structure.
1849	(314)	Northumberland	Spheroidal Basalt.
1850	(298)	Oatlands, Isle of Man	Granite. (M.)
1851	(294)	Phillipstown, Queen's C'nty	Tuff. (M.)
1852	(291)	Skye	Spheroidal Felsite. (M.)
1853	(322)	Londonderry	Ophitic Dolerite. (M.)
1854	(163)	Arran	Pitchstone. (M.)
1855	(333)	Atlantic	Globigerine Ooze. (M.)
1857	(325)	Fanad, Donegal	Contorted Limestone.

Photographed by A. S. REID, *Trinity College, Glenalmond, N.B.* 1/2.

2008	(HP 100)	Perthshire	Fold and fault in rock-specimen. 1898.

LIST II.

THE DUPLICATE (LOAN) COLLECTION.

The numbers placed after the description of the photograph refer to the list of names and addresses given at the end. The first refers to the photographer, who is also the donor in most cases. When he is not, the donor is indicated by a second number.

Full localities and descriptions are given in present and previous lists under the numbers.

This collection is arranged geologically, and from time to time the less perfect and less typical photographs will be removed and better ones substituted as they are given. Those laid aside can always be seen, sent, or returned by request.

* indicates that prints and slides may be bought from the photographer or from the address given at the end. P. indicates prints. S. indicates slides.

Examples of Different Rocks.

Regd. No.			
1763	Conglomerate (Carboniferous) .	Langness, Isle of Man.	1 S.
1885	,, Specimen of .	Hordwell.	1 P. S.
1836	Breccia ,, . .	Selsea.	1 P. S.
1887	Crinoidal Limestone (Carboniferous)	Flintshire.	1 P. S.
1839	Oolitic Limestone (Inferior Oolite)	Nailsworth, Glos.	1 P.
1840	Spore Coal	Moira, Leicester.	1 P. S.

Rock-Structures.

Bedding.

1998	Bedded Chalk	Thornwick Bay, Flamborough.	48 P.

Fossils in Rocks.

1838	Limestone	Dudley (Wenlock) Limestone.	1 S.

Evidences of Earth-movement.

Elevation and Submergence.

1885	Raised Beach	Saunton, Devon.	49 P.
1887	,, ...	,, ,,	49 P.

Folding and Faulting.

1887	Contorted Limestone . . .	Fanad, Donegal.	1 P.
2008	Fold and fault in rock specimen.	Perthshire.	15 P.
1927	Inner Pennine Fault . . .	Middle Tongue, High Cup Gill, York.	3 P.*

Unconformity.

1696	Lias on Carboniferous Limestone.	Southerndown, Glamorgan.	43 P.

Surface Agencies; Denudation and Deposit.

Running Water; Streams.

1802	Undercut waterfall . . .	Biglees Burn, Ayrshire.	15 P.
1803	,, ,, ...	,, ,,	15 P.

Caverns and Springs.

Regd. No.		
1804	Icicles showing line of springs	Entrance to Severn Tunnel, Monmouth. 41 P.

Wind Action.

460	Blown Sand, stratified	Leasowe, Cheshire. 10 S.

Action of Rain.

2	Earth Pillars	Botzen, Tyrol. 34 S.
3	,, ,,	,, ,, 34 S.

Glaciation; Glaciated Surfaces.

1906	Striæ on Granite	Wasdale Crag, Westmoreland. 3 P.*

Glaciation; Erratic and Perched Blocks.

1842	Glaciated Boulder (Limestone)	Doncaster. 1 P. S.

Glaciation; Boulder Clays.

1856	Boulder Clay	Railway, S. of Harlech. 1 P. S.

Volcanic and Plutonic Rocks.

Rock-masses and their Relations.

1286	Agglomerate (Precambrian)	Hanging Stone, Charnwood, Leicester. 1 S.
603	Granitite intrusive in Tremadoc rocks.	Foel Tan-y-Grisiau, Carnarvon. 31 S.
827	Intrusive masses in Ordovician rocks.	Yr Eifl, Nevin, Carnarvon. 25 S.
1909	Whin Sill in Carboniferous Limestone.	High Cup Nick, near Appleby. 3 P.*

Rocks and their Structures.

1800	Columnar Microgranite	Ailsa Craig. 15 P.
1801	,, ,,	,, 15 P.
1849	Spheroidal Basalt	Northumberland. 1 P.
1847	Amygdaloidal Basalt	Squire's Hill, Antrim. 1 P.
1848	Flow-structure in Rhyolite	Tardree, Antrim. 1 P.
1859	Porphyritic Pitchstone	Arran. 1 P.
1853	Ophitic Olivine-dolerite	Gortacloghan, Londonderry. 1 P.
1851	Tuff (Carboniferous)	Phillipstown, Queen's County. 1 P.

Characteristic Rocks and Landscapes.

Palæozoic.

857	Carboniferous Limestone	Burrington Combe, Mendip Hills. 2 P.
550	,, ,,	Eglwyseg Rocks, near Llangollen, Denbigh. 51 P.
551	,, ,,	Tynant Ravine, near Llangollen. 51 P.
552	,, ,,	,, ,, 51 P.
551*a*	,, ,,	Bron-heulog Quarry ,, 51 P.
163	Magnesian Limestone	Garforth, Yorkshire. 5 P.
1916	Lower Brockram Escarpment of Permian.	Near Hoff, Appleby. 3 P.*

Mesozoic.

1922	St. Bee's Sandstone (Trias)	Hilton Quarry, Appleby. 3 P.*
1595	Unconformity of Chalk on Trias	Murlough Bay, Antrim. 50, 9 P.*

Cainozoic.

Regd. No.			
224	Junction of Thanet Sand and Chalk.	Elham Valley Railway.	52 P.
226	Junction of Thanet Sand and Chalk.	„ „	52 P.
228	Junction of Thanet Sand and Chalk.	„ „	52 P.
231	Junction of Thanet Sand and Chalk.	„ „	52 P.
1758	Forest Bed Series . . .	E. of Cromer and near Trimingham, Norfolk.	8 P.
1787	Boulder of Chalk in Drift . .	W. of Cromer, Norfolk.	8 P.
1932	Moraines	Murton Pike, Westmoreland.	3 P.*
1825	Moraine, taken in snow . .	Loch Eunach, Cairngorm, Inverness.	46 P.

Names and Addresses of Donors and Photographers.

1. Professor W. W. Watts, Mason University College, Birmingham.
2. Professor F. J. Allen, Mason University College, Birmingham.
3. Godfrey Bingley, Thorniehurst, Headingley, Leeds.
   Transparencies of many of Mr. Bingley's photographs may be obtained from Messrs. Reynolds & Branson, Commercial Street, Leeds.
5. A. E. Nichols, 49 Reginald Terrace, Leeds.
8. A. Strahan, 28 Jermyn Street, S.W.
9. R. Welch, Lonsdale Street, Belfast.
10. C. A. Defieux, 50 Windsor Road, Tue Brook, Liverpool.
15. A. S. Reid, Trinity College, Glenalmond, Perth, N.B.
25. G. T. Atchison, Corndon, Sutton, Surrey.
31. G. J. Williams, Bangor, N. Wales.
34. R. Kidston, 24 Victoria Place, Stirling.
41. H. L. P. Lowe, Shirenewton Hall, Chepstow.
43. R. H. Tiddeman, 28 Jermyn Street, S.W.
46. W. Lamond Howie, Monton Lodge, Eccles.
48. H. Percy, High Street, Doncaster.
49. Miss E. M. Partridge, 75 High Street, Barnstaple.
50. Dr. W. F. Hume, Geological Survey Office, Cairo, Egypt. Donor.
51. G. H. Morton, 209 Edge Lane, Liverpool.
52. The late C. W. Allen.

Photographs of Geological Interest in Canada.—First Report of Committee, consisting of Professor A. P. COLEMAN (*Chairman*), Professor A. B. WILLMOTT, Professor F. O. ADAMS, Professor W. W. WATTS, Mr. J. B. TYRRELL, *and* Mr. W. A. PARKS (*Secretary*). (*Drawn up by the Secretary.*)

APPENDIX.—*Circular Letter issued by the Committee.*

WE have the honour to report that a meeting of this Committee was held as early as possible, at which it was decided to petition the Government for prints from negatives in its possession, and to issue a circular setting forth the purpose of the Association in forming this Committee. A small pamphlet was prepared and sent to the various camera clubs throughout the country, and to the science masters of high schools and other educational institutions.

As yet these efforts have borne no fruit, but we have formed a nucleus of forty negatives with prints, illustrating glacial phenomena in the vicinity of Toronto.

APPENDIX.

Circular Letter issued by the Committee.

TORONTO: March 15, 1898.

DEAR SIR,—At the meeting of the British Association for the Advancement of Science, held in Toronto in 1897, the following Committee was appointed for 'The collection, preservation, and systematic registration of Canadian photographs of geological interest.' Chairman, Professor A. P. Coleman; Secretary, Mr. Wm. A. Parks; Professor A. B. Willmott, Professor F. O. Adams, Professor W. W. Watts, and Mr. J. B. Tyrrell. This Committee has decided to appeal to those interested in geology and photography for assistance in preparing and improving the collection, which will be kept in Toronto, and will be at all times open to the public. The services of a competent photographer have been procured, and it is proposed to furnish lantern slides or prints to any desiring them at the cost of production.

The value of such a collection cannot be over-estimated, as it will furnish valuable material for the investigator or lecturer, it will preserve and place on record geological scenery of an evanescent nature, and will tend to stimulate geological investigation throughout the country.

We shall be glad to receive and place to the credit of the donor either negatives or prints of such subjects as are indicated in the following list, or others in any way related to geological science:—

Rocks and Rock Structure.—Cliffs and rock-surfaces showing stratification, false-bedding, character of weathering, foliation, jointage, cleavage, folding, faulting, veins, dikes, unconformities, contact zones of different kinds of rocks, minerals and mineral aggregates, fossils, &c.

Glacial Phenomena.—Moraines (stony hills), eskers, kames, perched boulders, glacial grooves and striæ, &c.

Shores.—Sand dunes, sand spits, lines of boulders, cliffs of sand and clay, ripple marks, &c.

Rivers.—Valleys, channels and gorges, banks in different conditions, terraces, bottom lands, &c.

Phenomena caused by Atmospheric Agencies.—Rain-marks, rill-channels, washouts, sun-cracks, &c.

New Railway Cuttings, Sand and Gravel Pits, &c.—It is of great importance that the exact locality and date accompany the photograph, and if possible the compass bearing of the centre of the picture from the camera.

Relying upon your co-operation, we request that you bring this communication to the notice of those interested in this work in your locality.

Very sincerely yours,

WM. A. PARKS, *Secretary.*

Address: WM. A. PARKS, B.A.
Geological Department, University of Toronto.

Irish Elk Remains.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), His Honour Deemster GILL, Rev. E. B. SAVAGE, Mr. G. W. LAMPLUGH, *and* Mr. P. M. C. KERMODE (*Secretary*), *appointed to examine the Conditions under which Remains of the Irish Elk are found in the Isle of Man.*

WE were able to add a foot-note to our report of last year to the effect that a fairly perfect skeleton had been discovered, of which we hoped to hand in details with this year's report.

These remains were found in a marl pit at Close-y-Garey, on the east side of the railway line, half a mile N. from St. John's, and the same distance S. from Poortown Station.

The bones were nearly all in juxtaposition and, excepting the ribs and pelvic bones and one shoulder-blade, in a very fair state of preservation. The antlers were nearly complete; the beams, however, are represented by fragments; the skull also is fragmentary.

The left antler is the larger: it measures across the palm 15 inches, allowing for a piece of the front edge which has decayed away; the right measures 13 inches. With the tines, most of which dropped off on lifting from the marl, they are respectively 56½ inches and 53 inches long, and the beam would have been about 10 inches more. They show six points, besides the brow-tines, which had fallen off, the portion of the beam to which they were attached having decayed away.

The palm of the left antler lay over the lumbar vertebræ, and the right over the fore-quarters. The upper jaw teeth were preserved on both sides, and those of the left lower jaw were embedded in the *ramus*. A fragment of the right symphysis was also present, and there were various fragments of a skull which had been broken up before the discovery.

Death had occurred in its full prime, as shown by the perfection of the teeth and the dimensions of the antlers.

Among the bones, but not of this individual, was one which had been perforated, probably by the point of an antler of another elk in one of their usual fights. It was fractured as well as perforated, and had been healed.

Professor Dawkins examined the bones in December and made the following measurements in millimetres:—

Skeleton found at Close-y-Garey. Index to Measurements.

Teeth.

1. Length, antero-posterior, basal.
2. Antero-transverse, basal.
3. Postero-transverse, basal.

Bones.

1. Maximum length.
2. Minimum circumference.
3. Transverse measurement of proximal articulation.
4. Vertical (tape) measurement of proximal articulation.
5. Transverse measurement of distal articulation.
6. Vertical (tape) measurement of distal articulation.

—	1	2	3	4	5	6
Scapula	463	182	72	70	—	—
Humerus	395	173	93	111	90	124
Ulna	490	90	30	59	20	20
Radius	390	145	89	45	80	44
Metacarpal	338	132	68	39	73	76
Femur	470	169	121	118	50 (patella)	120
Tibia	470	149	120	175	72	31
Metatarsal	373	132	65	35	72	83
Astragalus	86	86	53	42	58	39
Calcaneum	183	129	45	35	150	43
Scaphocuboid	(?) 50	223	75	40	69	55
Fore limb, ph. 1	78	98	35	35	32	38
„ ph. 2	58	100	55	22	29	65
„ ph. 3	85	—	30	30	—	—
Hind limb, ph. 1	79	95	35	35	34	38
„ ph. 2	60	102	34	22	30	62
„ ph. 3	82	—	28	33	—	—

Teeth (adult, worn).

—	1	2	3	—	1	2	3
U. M. Series	160	—	—	L. M. Series	170	—	—
M. 3	30	30	29	M. 3	42	20	19
M. 2	28	31	31	M. 2	21	20½	20
M. 1	25	28	28	M. 1	18	20	20
Pr. 4	19	26	—	Pm. 4	23	15	17
Pr. 3	18	23	—	Pm. 3	22	13	14
Pr. 2	22	22	—	Pm. 2	16	8	11

Excavation No. 1 *(disturbed soil).*

Fragments of Upper Jaw (teeth worn).

	1	2	3
M. 3	29	30	28
M. 2	28	30	30

The skeleton lay in white marl at a depth of about 9 feet from the present surface, on its right side, the legs drawn up to the body, the head towards the margin of the ancient pool, now a morass, which lies in a hollow in the glacial drifts.

From the position of the bones the animal appeared to have died where it was found, not to have been washed down by floods. About sixty years ago the bog had been worked for marl, and the present well-defined banks mark out a rectangular hollow some 50 yards square and about 3 feet below the surrounding surface.

Across one corner of this a trench was dug to carry off the water, and the operations of the Committee were confined to a triangular area on the west side of the trench, measuring about 15 yards east and west by about 30 yards north and south. They excavated all over this space to a depth of over 9 feet. The first four excavations, being through ground which had previously been disturbed, yielded no definite results, but at one point a few bones were met with, among which were fragments of maxilla, the sixth cervical vertebra, the second lumbar vertebra, and a fragment of a rib. In association with these were remains of horse represented by a radius and lower jaws of two individuals. Though the ground had been disturbed the horse bones probably belonged to the same age as the elk. A fragment of a metatarsal, met with in digging the trench, had an artificial perforation.

The result of all the excavations, allowing for the disturbed state of the ground, showed the following beds :—

	Ft.	In.
A. Disturbed soil and peat, an average of about	3	0
B. In one place a blue clay or silt was observed resting on the white marl		
C. White marl containing the Elk remains	6	6
*D. Blue marl	1	0
E. Red sand with gravel	0	3
F. Brown clay	0	3
G. Sand and gravel } ? Glacial drift	0	3
H. Clay	4	0

As stated above, the whole surface had been lowered about 3 feet in digging for marl ; the peat had for the most part been removed, and a great deal of the marl also ; indeed, we were fortunate in finding this one spot in which the marl itself had not been disturbed.

The finding of detached bones shows that other individuals had perished here, and is consistent with what we were told, that a specimen had been seen when digging for marl, and that the antlers of another had been taken out. We were told also that two skulls without antlers had been seen on the other side of our trench.

Samples of the marl and other beds were forwarded to Mr. James Bennie, of Edinburgh, who again most kindly undertook the laborious task of washing and sifting the material. The organic remains thus obtained were examined by Mr. Clement Reid, who has determined the following plants :—

From Peat B.

Ranunculus flammula, *L.*
Viola palustris, *L.*
Rubus fruticosus, *L.* (very small).
Potentilla tormentilla, *Neck.*
„ comarum, *Nestl.*
Carduus crispus, *L.*
Menyanthes trifoliata, *L.*
Empetrum nigrum, *L.*
Potamogeton, sp.
Carex, 4 sp.

Also beetles, 3 sp., and caddis cases.

From Marl C.

Ranunculus repens, *L.*
Viola palustris, *L.*
Potentilla comarum, *Nestl.*
Myriophyllum spicatum, *L.*
Rumex obtusifolius, *L.*
Empetrum nigrum, *L.*
Potamogeton.
Carex, 4 sp.
Chara.
Umbelliferous plant (unripe).

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* This was noticed below the skeleton, and may have been discoloured by the decay of the body.

From Red Sand E.

Plant remains, not determined.

From Bed F.

Betula alba.
Potamogeton.
Carex.
Bracts of sedge.
Leaves (?).

Mr. R. Okell examined the White Marl for Diatoms, but found no trace. There are no fresh-water shells in it.

In our last report we were able to announce the discovery in a previous excavation near Ballaugh of the Arctic crustacean Lepidurus glacialis, accompanied by the Arctic willow Salix herbacea in a bed of silt occurring above Chara-marl, like that of the present section. In that locality, however, we did not succeed in finding elk remains in the marl, probably on account of the limited character of our excavation, as we have every reason to believe that the skeleton now in Edinburgh Museum[1] was obtained from that bed. In the present instance, though we have found the elk, it will be noticed that the section contains no trace of the Arctic fauna. This is greatly to be regretted, since—as was pointed out by Mr. C. Reid in our last report—the relation of this fauna to the bed containing the elk is a point of great theoretical importance. It is also important that the presence of the horse in the wild fauna of the Isle of Man should be placed beyond doubt by working in undisturbed ground. The same group of animals may be expected as that which occurs in the prehistoric strata of Ireland and England. Under these circumstances we propose to apply for a further grant to carry on explorations which will probably definitely settle these interesting questions.

The balance of the grant, renewed last year, was expended in the preliminary work of draining; further funds, which enabled the Committee to continue the work and to discover the specimen, were provided by the local Society, which also provided the amount required for having the skeleton mounted.[2]

The best thanks of the Committee are due to the proprietor, Mrs. Morrison, for kind permission to make the excavations, and Messrs. C. Reid, J. Bennie, and R. Okell for the valuable assistance they have rendered in the investigation.

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[1] This is interesting as being the first perfect skeleton of this species to have been mounted. Dr. Traquair writes concerning it that when he took office he found that the pelvis in the skeleton was that of a common horse, which he had replaced by that of a real elk from Ireland. He gives the following measurements (in inches): Humerus 15, radius 14$\frac{1}{4}$, metacarpal 13$\frac{1}{4}$, femur 18, tibia 19$\frac{1}{2}$, metatarsal or cannon 14$\frac{1}{4}$; distance from tip to tip of the antlers, 8 feet 1$\frac{1}{4}$ inches. He also points out that the figure in Cuvier's *Ossemens Fossiles* (and in Owen's *Fossil Mammals*) represents this skeleton exactly as it was before he had it altered by replacing the horse pelvis with that of the Irish elk, and giving a proper curve to the vertebral column, which formerly was absolutely straight, in the dorsal and lumbar regions.

[2] It has now been set up in Castle Rushen, Isle of Man.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Professor E. HULL (*Chairman*), Professor T. G. BONNEY, Professor W. J. SOLLAS, Mr. C. E. DE RANCE, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Mr. J. HORNE, *the late* Mr. DUGALD BELL, Mr. F. M. BURTON, Mr. J. LOMAS, *and* Mr. P. F. KENDALL (*Secretary*), *appointed to investigate the Erratic Blocks of the British Isles, and to take measures for their preservation. (Drawn up by the Secretary.)*

THE Committee has to deplore the loss of a valued colleague, Mr. Dugald Bell, whose death has deprived British geology of a most careful, conscientious, and industrious worker.

The records obtained by the Committee during the past year have been drawn from a smaller area than usual, and the number of individual boulders specifically reported is not large.

The Sub-Committee, working at the instance of the Belfast Naturalists' Field Club, has deferred its report pending the completion of certain definite pieces of investigation. The Committee organised in County Durham has not yet presented a report, though observations of considerable interest have been made during the preliminary examination of portions of the district covered by it, notably the discovery of several fine striated rock-surfaces.

The Lincolnshire Boulder Committee has presented reports for the years 1896–7 and 1897–8, and the Yorkshire Boulder Committee has, as usual, furnished a valuable and significant set of records.

Some facts of great importance have been brought to light, which are particularised in the sequel. The discovery of two large glaciated boulders of chalk near Scarborough is of interest, as that point is fully 20 miles to the northward of the chalk cliffs of the Yorkshire coast.

Attention was directed last year to the remarkable fact that the *Belemnitellæ* collected from the drift of Holderness belonged without exception to the species *B. lanceolata*, which is unknown as a constituent of the fauna of the Yorkshire chalk, which contains instead *B. quadrata*. This conclusion is fully sustained by the work of the past year, and emphasises the well-known fact that *black* flints, which are unknown in the local chalk, are found plentifully in the glacial deposits of the Yorkshire coast. One such flint, containing a cast of *Echinocorys*, is reported from an inland station, Market Weighton.

Further valuable work has been done upon the distribution of boulders of Shap granite, and their sporadic grouping receives a fresh illustration from the Scarborough coast.

Further light is thrown upon the source of the in many ways anomalous patch of boulder-clay at Balby by the discovery in it of three specimens of Eskdale granite.

Our knowledge of the distribution of erratics of Scandinavian origin receives a welcome addition by the observation of a second example of the granite from either Angermanland or Aland (Sweden) at Easington, and by the recognition of a pebble of rhomb-porphyry at Brough. The latter is the first undoubted occurrence of a Scandinavian boulder within the line of the Chalk Wolds.

The Committee is also enabled to announce the recognition amongst the far-carried erratics of the East Coast of England of a considerable number of Norwegian rocks from localities which were not previously known to have yielded boulders to the English drift.

The Secretary spent a month during the summer of 1897 in Norway, between Christiania and Christiansand, collecting rocks for comparison with the erratics of the East Coast of England. He brought away a large quantity of material illustrating important petrological types, and has now distributed about 300 specimens amongst English workers in glacial geology, to whom they may be useful. Other sets will be lodged in public museums. A series of East Coast erratics, collected by Mr. J. W. Stather, F.G.S., and Mr. Thomas Sheppard, was taken to Christiania and submitted to Professor Brögger, who had kindly consented to examine them. Professor Brögger's examination was not carried to completion, as the thin sections which should have accompanied the specimens had gone astray in the post, but some rocks were nevertheless singled out by him which possessed such marked characteristics as to permit of positive identification. These determinations are of so much interest and importance that it has been thought desirable to publish them in this report rather than to wait for a more complete statement.

The well-known *Rhomb Porphyries* yielded examples from the Ringerike, Tonsberg, and Tuft (in the Langendal districts).

Laurvikite (Augite-Syenite) of the type which prevails over such large areas southward of the latitude of Christiania was recognised. These are rocks with which English geologists have for some time been familiar; but, besides these, Professor Brögger found the *Pyroxenite* of Fettnedt, Christianiafjord; a basic rock from Hitterdal (this is a very pronounced type, regarding which Professor Brögger spoke with great confidence); the Labradorite-porphyrite of Mos (on the east side of the Skager Rock south of Dröbak); and rocks from the neighbourhood of Drammen. In addition to these, there are examples of a *Labradorite porphyrite* with porphyritic conspicuously zoned felspars, which is known as an erratic in Norway, but has not been traced *in situ*.

Finally, Professor Brögger recognised three examples of sandstone or grit representing the curious *Sparagmit conglomerat*, which covers a vast area in the high mountainous interior of Scandinavia northward of Christiania. The specimens in question may have come from Gudbrandsdal, about the northern part of Lake Mjesen.

A coarse granite collected by Mr. Sheppard, Professor Brögger considered to resemble the rocks of Ragunda in Angermanland, a conclusion confirmatory of Dr. Munthe's recognition of a boulder composed of a similar rock (see 1897 Report, p. 351), and which occurs also, according to Mr. Crofts, at Easington (see p. 554).

YORKSHIRE.[1]

Communicated by the Yorkshire Boulder Committee.
Secretary, Mr. J. H. HOWARTH, *F.G.S.*

Reported by Mr. W. GREGSON, *F.G.S.*

Mount Grace Priory, 7 miles E. of Northallerton—

1 Shap granite.

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[1] This report will be published *in extenso* in the *Naturalist.*

Reported by Mr. J. Burton.

Balby, near Doncaster—

3 Pebbles of Eskdale granite.

Reported by Mr. P. F. Kendall.

Market Weighton.—Gravel pit one mile from town on the road to Holme.

Nodule of black flint with *Echinocorys vulgaris.*

Reported by Mr. W. H. Crofts.

Easington—

1 Specimen of 'Post Archæan Granite' of Angermanland or Aland, Sweden.

Reported by Mr. J. F. Robinson.

Wassand, near Hornsea—

1 Coarse basalt.

Reported by Mr. Harold Sales.

Willerby, near Hull.—38 Boulders, comprised of—

6 Carboniferous limestones; 15 basalts; 6 sandstones (probably Carboniferous); 3 Jurassic rocks; 8 granites, gneisses, &c.

One pebble of rhomb porphyry. Many black flints and several examples of *Belemnitella lanceolata*, which are not known to occur in the Yorkshire Chalk. Lower Lias fossils.

Reported by Mr. J. W. Stather.

Scalby Mills, Scarborough.—From a section of Boulder-clay many hundreds of boulders had been extracted. Between 50 and 75 per cent. were of Estuarine sandstone from the subjacent beds. The remainder consisted of Carboniferous rocks, basalt, other igneous rocks, and some Secondary rocks, including two planed and striated blocks of chalk, each about 8 feet in diameter.

Burmiston, north of Scarborough.—In the bay one mile long between Cromer Point and Long Nab.

11 Shap granites.

Cloughton.—In quarry W. of the village.

1 pebble of hard chalk.

Easington—

3 Shap granite (in addition to those recorded in earlier reports)

Several examples of *Belemnitella lanceolata.*

Reported by Mr. Thomas Sheppard.

Atwick—

1 Red gneiss; 1 hornblendic gneiss; 1 Shap granite.

Brough.—Mill Hill Gravel pit 100 feet above O.D.

1 Rhomb porphyry.

Dimlington—

1 Augite-syenite (Laurvikite) embedded in the 'Basement' Boulder-clay; 1 rhomb porphyry.

Easington. On the Beach—

1 Shap granite, 1 rhomb porphyry, besides granite, gneiss, basalt, augite-syenite, Carboniferous Limestone, gannister, carboniferous basement-conglomerate, brockram, Magnesian Limestone, Lias, secondary nodule with *Crioceras* (probably from the Speeton clay), black and pink flints.

Garton. In farmyard near Grimston Hall.
The following stones were obtained from the Beach :—

Carboniferous basement-conglomerate; 1 lias (with fossils); 1 gneiss; 1 Millstone Grit; 1 Carboniferous Limestone; 1 gannister; 1 grey granite.

Besides these were the following picked off the fields :—

1 Lias (striated); 1 basalt; 2 basalt (striated); 1 rhomb porphyry; 1 gannister; 1 quartzite; 1 porphyrite.

Hornsea—

1 Shap granite pebble found *in situ* in 'Purple' Boulder-clay.

Patrington, Skeffling, Weeton and Welwick.—In all these villages great numbers of boulders occur, amongst which the following were noted :—

Basalt, gneiss, porphyrite, rhomb porphyry, Carboniferous Limestone, and Sandstone, Lias, flint, &c.

Withernsea—

2 Shap granite; 1 compact blue gneiss.

About 3 dozen specimens of *Belemnitella,* all of the species *B. lanceolata.* In the large collection of Mr. G. Miles at Withernsea the Belemnitellas are also exclusively of this species.

About 20 Chalk echinoderms, mostly in black flint such as is not known *in situ* in Yorkshire.

LINCOLNSHIRE.

Reported by Mr. J. W. STATHER.

Louth—

1 Basic rock from Hitterdal, Norway.

Communicated by the Lincolnshire Boulder Committee.
Secretary, Rev. W. TUCKWELL.

Brigsley—

1 Sandstone; 2 grey sandstone; 1 whin sill; 1 basalt (not whin sill).

East Ravendale—

5 Sandstone; 2 whin sill.

Beechby—

1 Quartzite.

Barnoldsby—

1 Whin sill.

Great Coates.—Heap of pebbles near the Station included :—

1 Basalt (like loadstone) ; 1 rhomb porphyry ; 1 red granite ; 1 grey granite ; 1 Oolitic limestone.

Near Mr. Cordeaux's house—

1 Limestone much weathered ; 1 crystalline limestone ; 1 micaceous limestone ; 2 schists ; 1 rolled porphyritic granite trawled from the Dogger Bank.

In Pit by Railway Station.—Smaller rolled pebbles including :—

1 Schist ; 2 micaceous sandstones ; 1 crystalline limestone.

Humberstone—

5 Whin sill ; 1 basalt ; 4 grey sandstone ; 1 quartzite.

Bradley Wood—

3 Whin sill.

Bradley—

2 Quartzites ; 2 white sandstones ; 1 granite ; 3 yellow sandstones ; 1 basalt ; 1 'Blue stone.'

Aylerby—

5 Whin sill ; 1 pale sandstone ; grey granite ; red granite.

Structure of a Coral Reef.—Report of the Committee, consisting of Professor T. G. BONNEY (*Chairman*), Professor W. J. SOLLAS (*Secretary*), Sir ARCHIBALD GEIKIE, Professors J. W. JUDD, C. LAPWORTH, A. C. HADDON, BOYD DAWKINS, G. H. DARWIN, S. J. HICKSON, *and* ANDERSON STUART, Admiral Sir W. J. L. WHARTON, Dr. H. HICKS, Sir J. MURRAY, Drs. W. T. BLANFORD, C. LE NEVE FOSTER, *and* H. B. GUPPY, Messrs. F. DARWIN, H. O. FORBES, G. C. BOURNE, *and* J. W. GREGORY, Sir A. R. BINNIE, *and* Mr. J. C. HAWKSHAW, *appointed to consider a project for investigating a Coral Reef by Boring and Sounding.*

THE boring into the coral reef at Funa Futi, under the superintendence of Professor Edgeworth David, was carried down to a depth of 643 feet. After he had quitted the island to return to Sydney the work was continued until, owing to a breakdown of the apparatus, it finally ceased at a depth just short of 700 feet. The cores obtained during the work have been forwarded to England, and are now being worked out under the supervision of Professor Judd in the laboratory of the Royal College of Science at South Kensington. A brief summary of the results down to 643 feet was presented to the Royal Society on November 25, 1897, and will be found in their 'Proceedings.' According to the survey of Funa Futi and the neighbouring seas made by Captain Field, of H.M.S. 'Penguin,' it appears that the shape of the former is that of a cone with a rudely elliptical base rising with a gradual slope from the ocean floor at a depth of about 2,000 fathoms, and forming a kind of mural escarpment for the last 750 feet (approximate). When the whole party had returned to Sydney, Professors David and Stuart, after discussing the question of renewing the attempt to pierce the reef, the bottom of which, from the change of slope mentioned above, they thought must lie within 800 feet of the surface, prevailed on the authorities of the Department of Mines, Sydney, to lend plant and workmen in order to continue the old bore-hole and, if possible, to put down another one in a shallow part of the lagoon. Application was made to the Admiralty by the Royal Society, and permission was given for the members of the expedition and the plant to be conveyed from Suva to Funa Futi and back by H.M.S. 'Porpoise.' The expedition has been at work during the summer, and intelligence of the result will doubtless reach England during the present autumn. Until this arrives, and the study of the materials already in this country has been completed, it would be premature to express any opinion of the theoretical bearing of the results obtained by the very successful operation undertaken in 1897.

The sum of 40*l.* granted at Toronto by the General Committee at Toronto has been drawn by the Chairman and remitted to Professor Edgeworth David in aid of the expenses of the expedition of 1897 (which have been heavier than was anticipated).

The Eurypterid-bearing Rocks of the Pentland Hills.—Final Report of the Committee, consisting of Dr. R. H. TRAQUAIR (*Chairman*), Mr. M. LAURIE (*Secretary*), *and* Professor T. RUPERT JONES.

THE work of your Committee on this fossiliferous bed is now completed. As mentioned in a former report the method adopted was to remove a considerable section of the bed which is comparatively thin, and transport it to a more accessible place where the rock was carefully split. This mode of procedure had the advantage of enabling us to deal with a much greater amount of material than could have been gone over at the locality itself. On the other hand, the highly jointed nature of the rock rendered it difficult to transport it in large pieces, and many of the specimens are consequently fragmentary. Nevertheless, a few very fine specimens have been procured, notably an almost complete *Drepanopterus pentlandicus*, and a large amount of fresh information has been gained as to the structure of other forms. The presence and structure of the preoral cheliuræ in *Stylonurus* have been ascertained, as well as nearly all the details of the other appendages of this form. Some hitherto undescribed forms, including a new genus, *Bemlycosoma*, of somewhat doubtful position among the Eurypteridæ, have also come to light. The type specimens of these new forms are, however, not in this collection, as they were all represented by better specimens in a private collection which recently became available for examination, having been acquired by the Edinburgh Museum of Science and Art. These, as well as the more instructive specimens from the collection formed by your Committee, have been described and figured this year in the 'Transactions of the Royal Society of Edinburgh.'

One of the points which your Committee had to decide was the stratigraphical position of the bed. They came to the conclusion, from the fossils present in it and the neighbouring beds that it must be considered as being on the Wenlock horizon. It is unnecessary to deal with the evidence which led to this conclusion, as the Scottish Geological Survey have this year been revising the district, and in their new monograph on it come to the same conclusion. This bed is, therefore, at a distinctly lower horizon than most of the other deposits which have yielded Eurypterids. This agrees with the fact that some of the forms, such as the three species of *Drepanopterus*, are not highly specialised types. The representatives of the genera *Slimonia* and *Stylonurus* have also certain of the generic characters less markedly developed than the forms from higher horizons. On the other hand, the presence of such a large number of genera point to the origin of this group being in much lower deposits than have yet yielded their remains.

Your Committee are well satisfied with the results of the investigation, which has yielded much new and interesting information, though it is to be regretted that they were unable to procure specimens of some of the forms, such as *Palæophonus*, which have been found by other collectors. The chief species represented in the collection are: *Stylonurus ornatus, S. macrophthalmus, Drepanopterus pentlandicus, D. bemlycoides, Bemlycosoma.*

The Zoology of the Sandwich Islands.—Eighth Report of the Committee, consisting of Professor A. NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, [*the late*] Mr. O. SALVIN, Dr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THE Committee was appointed in 1890, and has been annually reappointed. Since the last report (at Toronto) work on the collections of insects, &c., has been continued by Mr. R. C. L. Perkins, Mr. E. Meyrick, and others, and the Committee hopes to be able soon, with the aid of the Royal Society and the B. P. Bishop Museum, to publish a volume. A large number of specimens have been sent to the British Museum (Natural History) and to the B. P. Bishop Museum in Honolulu.

The Committee has suffered a serious loss by the decease of Mr. O. Salvin, who was a most useful member from the time of its first appointment.

The Committee requests its reappointment, with Mr. F. Du Cane Godman, F.R.S., in the place of the late Mr. Salvin.

Zoological Bibliography and Publication.—Interim Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Professor W. A. HERDMAN, Mr. W. E. HOYLE, Dr. P. L. SCLATER, Mr. ADAM SEDGWICK, Dr. D. SHARP, Mr. C. D. SHERBORN, Rev. T. R. R. STEBBING, Professor W. F. R. WELDON, *and* Mr. F. A. BATHER (*Secretary*).

IN its last report the Committee recommended its reappointment, mainly for the purpose of distributing copies of that report to the editors of all publications connected with zoology, and for that purpose it further asked for a grant of 6*l.* 1*s.* for expenses of printing and postage. The Committee was reappointed, but without a grant; an omission which has considerably restricted its action and caused it to postpone the preparation of any further report. There are signs that the previous recommendations of the Committee are being put into practice in various quarters, and it seems probable that a renewal of its exertions would lead to still further satisfactory results. The Committee therefore begs to renew its application for the above grant in order that it may carry out the work already sanctioned.

Life Conditions of the Oyster: Normal and Abnormal.—Third and Final Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Professor R. BOYCE (*Secretary*), Mr. G. C. BOURNE, Dr. C. A. KOHN, *and* Professor C. S. SHERRINGTON, *appointed to Report on the Elucidation of the Life Conditions of the Oyster under Normal and Abnormal Environment, including the Effect of Sewage Matters and Pathogenic Organisms.* (*Drawn up by* Professor HERDMAN, Professor BOYCE, *and* Dr. KOHN.)

THE Committee are bringing their investigations to an end for the present, and they now state in this final report a series of the conclusions at which they have arrived. The details of the evidence upon which these conclusions are based will appear in a fully illustrated memoir by Professor Boyce and Professor Herdman, which is nearly ready for publication. A good deal of that evidence has, however, been outlined in our former reports (at Ipswich, Liverpool, and Toronto), and need not be now repeated.

Since last year's report, however, we have gone further into the question of the amount of copper and iron present in different parts of various kinds of oysters, with results which sustain the conclusions we had already arrived at.

We have also gone more minutely into the question of typhoid-like organisms, their occurrence in shellfish, and the differentiation of these from the *B. coli communis* on the one hand, and from the true *B. typhosus* on the other, with the following results :—

Bacteriology of Shellfish.

In one of our previous reports (B.A., Liverpool, 1896) we drew attention to the comparatively frequent occurrence of a group of organisms giving the reactions of the *Bacillus coli*, and also of a motile bacillus, which, owing to the fact that it did not behave like the Colon bacillus in all its reactions—*i.e.*, formation of indol and gas bubbles, approached somewhat the *B. typhosus* type. Shortly after the publication of that paper, Dr. Klein drew attention, in the very comprehensive Local Government Board Report, upon 'Oyster Culture in Relation to Disease,' to the frequency of the presence of the Colon bacillus in oysters, and in one instance to the presence of a bacillus, which, after most careful investigation, could not be distinguished from the bacillus of Eberth. Since that date we have continued our investigations upon the bacteria present in oysters, and have further extended them to other shellfish. We have examined, during the last year, 19 batches of oysters, 17 batches of mussels, 18 batches of cockles, 5 batches of periwinkles, and 1 batch of whelks ; these were obtained from shops in various parts of Liverpool.

Methods.—The methods employed were similar to those detailed in our report previously referred to, except that we availed ourselves of the serum reaction ; and we desire to express our thanks to Dr. Christophers, who especially undertook the investigation of the serum reaction in connection with all the 'coli' and typhoid-like organisms which were isolated in the laboratory.

Results.—Oysters.—In nine out of the nineteen batches a colon-like organism was isolated from the interior of the oysters. In some instances there was almost a pure culture of the Colon bacillus, the Petri dishes giving a very characteristic odour. The reaction in the nine cases differed; there was the typical colon group, coagulating milk, forming indol and gas, and giving a decided acid reaction, as well as an abundant growth upon potato. There was also a group consisting of very active bacilli, not coagulating milk, not forming indol, occasionally forming gas, and in two cases giving rise to a slightly acid reaction in neutral litmus whey, and in three cases to an alkaline reaction. In each suspicious case the serum reaction was carefully tried, but always with negative results. We conclude that this latter group, although giving some of the reactions of the typhoid bacillus, cannot be regarded as identical with the true bacillus of Eberth.

Mussels.—The colon group is less frequent; some of the bacilli isolated coagulated milk, formed gas and indol, whilst others gave negative reactions, as in the case of the oysters.

Cockles.—A colon bacillus was not isolated. A coccus not liquefying gelatine, growing at a temperature of 37° C., and sometimes forming gas, was frequently met with.

Periwinkles.—As in the case of the previous group, a coccus was isolated.

Whelks.—From these a bacillus was obtained, which formed gas at 37° C., did not coagulate milk nor produce indol, and only after four days produced a slight acid reaction in neutral litmus whey; it therefore resembled the second group found in the oyster.

These observations show the frequent occurrence of the Colon group of bacilli in such shellfish as we have investigated. Moreover, they clearly indicate that some of the organisms composing this group are more closely related in their reactions to the *Bacillus typhosus* than others are, although none corresponded to that bacillus in all respects. It will be remembered that in our Liverpool Report (1896) we described the occurrence of the typhoid organism after various intervals of time in oysters which we had experimentally infected with typhoid material. To that report[1] we may refer also for a discussion of the results of washing infected oysters in a running stream of sea-water, and for a statement of the diminution of the number of typhoid organisms as the time of inoculation recedes. In our Ipswich paper[2] we had shown that oysters were able to live, and did live, under very impure conditions, and were able to make use of sewage matter as food. We also demonstrated (in 1895) by experiments that those laid down in the proximity of drains contained far more micro-organisms than such as were some distance off in purer water. Finally, in last year's report at Toronto,[3] we gave an account of the unhealthy condition of certain green oysters, of the association of the colour with a leucocytosis, and of the presence of copper in the leucocytes.[4]

As the result of these various lines of investigation, and of the examination of oysters alive under both natural and artificial conditions on

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[1] *Brit. Assoc. Rep.*, Liverpool Meeting, 1896, p. 663.
[2] *Ibid.*, Ipswich Meeting, 1895, p. 723.
[3] *Ibid.*, Toronto Meeting, 1897, p. 363.
[4] See also *Proc. Roy. Soc.*, vol. lxii. p. 30.

various parts of the British, French, Dutch, and Italian coasts, we have arrived at the definite conclusions as to their natural history, chemistry, and bacteriology, which are detailed below; and to which we have ventured to add some recommendations as to administrative and public health questions. We are convinced that all that is necessary in order that the oyster may be restored to its proper position in public estimation as a most useful, delicate, and nutritious food-matter is that shellfish importing, growing, and laying shall be conducted under proper supervision, and that the grounds and waters chosen for the purpose should be inspected and licensed by duly qualified scientific authorities

Conclusions.

1. There are several distinct kinds of greenness in oysters. Some of these, such as the green Marennes oysters and those of some rivers on the Essex coast, are healthy; while others, such as some Falmouth oysters, containing copper, and some American oysters re-bedded on our coast, and which have the pale green leucocytosis [1] we described in the last report, are not in a healthy state.

2. Some forms of greenness (*e.g.*, the leucocytosis) are certainly associated with the presence of a greatly increased amount of copper in the oyster, while other forms of greenness (*e.g.*, the Marennes) have no connection with copper, but depend upon the presence of a special pigment marennin, which may be associated with a certain amount of iron.

3. We see no reason to think that the iron in the latter case is taken in through the surface epithelium of the gills and palps, but regard it, like the rest of the iron in the body, as a product of ordinary digestion and absorption in the alimentary canal and liver.

4. We do not find that there is any excessive amount of iron in the green Marennes oyster compared with the colourless oyster, nor do the green parts (gills, palps, &c.) of the Marennes oyster contain either absolutely or relatively to the colourless parts (mantle, &c.) more iron than colourless oysters. We therefore conclude that there is no connection between the green colour of the 'Huîtres de Marennes' and the iron they may contain.

5. On the other hand, we do find by quantitative analysis that there is more copper in the green American oyster than in the colourless one; and more proportionately in the greener parts than in those that are less green. We therefore conclude that their green colour is due to copper. We also find a greater quantity of iron in these green American oysters than in the colourless; but this excess is, proportionately, considerably less than that of the copper.

6. In the Falmouth oysters, containing an excessive amount of copper, we find that much of the copper is certainly mechanically attached to the surface of the body, and is in a form insoluble in water, probably as a basic carbonate. In addition to this, however, the Falmouth oyster may contain a much larger amount of copper in its tissues than does the normal colourless oyster. In these Falmouth oysters the cause of the green colour may be the same as in the green American oysters.

7. The Colon group of bacilli is frequently found in shellfish, as sold in towns, and especially in the oyster; but we have no evidence that it

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[1] Mr. G. C. Bourne informs us that in 1890 he examined some green oysters from Falmouth which showed this leucocytosis. (See Note by Mr. Bourne at conclusion of this report, p. 569.)

occurs in Mollusca living in pure sea-water. The natural inference that the presence of the Colon bacillus invariably indicates sewage contamination must, however, not be considered established without further investigation.

8. The Colon group may be separated into two divisions—(1) those giving the typical reactions of the Colon bacillus, and (2) those giving corresponding negative reactions, and so approaching the typhoid type; but in no case was an organism giving all the reactions of the *B. typhosus* isolated. It ought to be remembered, however, that our samples of oysters, although of various kinds and from different sources, were in no case, so far as we are aware, derived from a bed known to be contaminated or suspected of typhoid.

9. Consequently, as the result of our investigations, and the consideration of much evidence, both from the oyster-growers' and the public health officers' point of view, we beg to recommend—

(*a*) That the necessary steps should be taken to induce the oyster trade to remove any possible suspicion of sewage contamination from the beds and layings from which oysters are supplied to the market. This could obviously be effected in one of two ways, either (1) by restrictive legislation and the licensing of beds only after due inspection by the officials of a Government Department, or (2) by the formation of an association amongst the oyster-growers and dealers themselves, which should provide for the due periodic examination of the grounds, stores, and stock by independent properly qualified inspectors. Scientific assistance and advice given by such independent inspectors would go far to improve the condition of the oyster beds and layings, to re-assure the public, and to elevate the oyster industry to the important position which it should occupy.

(*b*) Oysters imported from abroad (Holland, France, or America) should be consigned to a member of the 'Oyster Association,' who should be compelled by the regulations to have his foreign oysters as carefully inspected and certificated as those from his home layings. A large proportion of the imported oysters are, however, deposited in our waters for such a period before going to market that the fact of their having originally come from abroad may be ignored. If this period of quarantine were imposed upon all foreign oysters a great part of the difficulty as to inspection and certification would be removed.

(*c*) The grounds from which mussels, cockles, and periwinkles are gathered should be periodically examined by scientific inspectors in the same manner as the oyster beds. The duty of providing for this inspection might well, we should suggest, be assumed by the various Sea Fisheries Committees around the coast.

APPENDIX.

Notes on the Occurrence of Iron and of Copper in certain Oysters.

By CHARLES A. KOHN, *B.Sc., Ph.D.*

The investigations of Professors Herdman and Boyce on the life conditions of oysters, which have been in progress since 1895, have pointed to the desirability of ascertaining the quantities of iron and of copper they may contain under either normal or abnormal conditions.

Two points of interest have arisen in this connection. In the first place the relation of iron to the greenness of the healthy French oyster ('Huître de Marennes'); and secondly, the extent to which copper is responsible for the pale green colour of American and other oysters, a diseased condition accompanied by a leucocytosis discovered and especially studied by Herdman and Boyce. The presence of minute quantities of copper and of iron as normal constituents of all oysters has also been shown by the analytical data obtained.

The results recorded have been made at Professor Herdman's request, and have proceeded side by side with his investigations. Now that these are completed, a summary of the work from a more purely chemical standpoint may be of interest, especially since the occurrence of these metals—copper and iron—either from the point of view of the origin of colouration or of the cause of poisoning has from time to time been the subject of discussion.

The Analytical Method employed.—Electrolytic methods of analysis were adopted both for the determination of iron and copper: these methods, I have already shown,[1] possess marked advantages for the estimation of minute quantities of metal, especially if derived from organic matter, for they are quite free from any prejudicial influences traces of organic matter may exert, such as arise when volumetric or colorimetric methods are employed. In each determination the bodies or gills only of six or more oysters were carefully washed, dried between filter paper to remove as much adherent moisture as possible, and then carefully dried in porcelain dishes in the air bath at 100° C. When this drying was as complete as possible, the oysters were heated in the air bath until thoroughly carbonised, the carbon carefully burnt off over the free flame, and the residue finally ignited in a porcelain crucible. Special care was taken to exclude dust during both the drying and the ignition. The ash was then thoroughly extracted with a mixture of 25 c.c. hydrochloric acid and 25 c.c. sulphuric acid (1:2) on the water bath, and the resulting solution filtered and concentrated. The residue was free from both copper and iron. The acid solution obtained was electrolysed for copper with the usual precautions, a spiral of fine platinum wire weighing about 5 grme. being employed as the cathode. The iron was determined in the residual solution, after neutralisation with ammonium hydrate, &c., acidifying with a few drops of oxalic acid solution, and boiling with ammonium oxalate: 4 grme. of the oxalate were added in each case, the precipitated calcium oxalate (which is quite free from iron) filtered off and thoroughly washed and the resulting solution electrolysed, the metallic iron being also deposited on a spiral of platinum wire. A blank experiment with all the reagents employed was made, and the amount of metal found (0·0002 grme. iron) deducted in each case. Also the deposited metal, both iron and copper, was dissolved off the electrode by acid, the solution obtained tested by the ordinary reagents and the spiral reweighed, as a check upon the determinations, since the quantities found were extremely small.

The Green Colour of French Oysters, 'Huîtres de Marennes,' and the Presence of Iron in Oysters.—The early observations of Dumas (1841) and of Berthelot (1855) showed that the green colour of 'Huîtres de Marennes' is not due to chlorophyll, and that although every oyster con-

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[1] *Brit. Assoc. Rep.*, 1893, p. 726.

tains a certain very small amount of copper in its blood in the form of 'hæmocyanin,' as determined by Fredericq, the green colour of the French cultivated oyster is not due to this metal. Ray Lankester[1] in 1886 confirmed the latter statement, and states in his investigation on the histological condition of the colour that there is neither copper nor iron in the refractory blue pigment 'marennin' of the coloured portions of the oyster. Berthelot, however, suggested that the green colour was probably due to iron, and more recently Chatin and Muntz[2] have extended and corroborated this statement.

From their analytical results these observers conclude that both the green and brown colourations of various types of French oysters are due to the presence of iron, and that the depth of colour bears a close proportion to the quantity of iron contained. The colourations are chiefly apparent in the gills, but extend also to the labial palps and parts of the alimentary canal. Chatin and Muntz base their conclusions in the first place upon the fact that they find considerably more iron in the gills than the rest of the body of green oysters; and secondly, upon the occurrence of a larger quantity of iron in the gills of green than of white oysters.

Appended are some of their results, to which I have added a column showing the ratio of the iron in the body, minus gills, to that contained in the gills.

Oyster	Colour	Iron per 100 parts of dried organic matter		Ratio of II.:I.
		I. Gills	II. Rest of body	
Cancale . . .	White . . .	0·0379	0·0241	1·57
Arcachon . .	Pale green . .	0·0605	0·0357	1·69
Marennes . .	Very green . .	0·0702	0·0318	1·21
Cancale . . .	Brown green . .	0·0804	0·0476	1·69
Sables d'Olonne .	Very dark brown green	0·0833	0·0436	1·91

The relative proportion of iron in the gills hardly bears out the conclusions arrived at; it is the same in pale-green and brown-green oysters, and in both, but little greater than in the white. On the other hand, the total iron, both in the gills and in the rest of the body, shows a marked increase, apparently corresponding to the depth of the colouration. The iron was determined in these experiments by potassium permanganate, but the absolute quantities of metal found are not stated. The calculation of the results per 100 parts of dried organic matter is apt to be misleading. In my own experiments it was not found possible to get anything approaching constant weights in this way, and the results are entirely out of accord with those of Chatin and Muntz.

The following table gives the quantities of iron found in French as compared with white American oysters, three pairs of gills being analysed in each case.

These figures show conclusively that there is more and not less iron in the gills of the white American oysters than in the French, and this irrespective of the basis on which the result is calculated. The ash is undoubtedly the most reliable factor to calculate on, provided the oysters

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[1] *Quart. Journ. Micros. Sci.*, 1886, 26, 71.
[2] *Compt. Rend.*, 1892, 118, 17, and 56.

are carefully washed before drying, which was always done: the result per pair of gills (or oyster) is most in accord with this, and has the advantage of being an easy and in many respects useful basis.

—	Huîtres de Marennes	American
Gross body weight, after drying between filter paper	3·8 grme.	6·5 grme.
Weight dried at 100° C. for 6 hours	0·52 „	1·02 „
Weight of ash	0·0940 „	0·1140 „
Weight of *Iron* found	0·0003 „	0·0008 „
Ratio of Iron found:—		
(1) Calculated per pair of gills	1 to	2·7
(2) „ on gross body weight	1 to	1·56
(3) „ on weight at 100° C.	1 to	1·36
(4) „ on ash	1 to	2·2

The relative quantities of iron present in the gills as compared with the rest of the body were next determined in French, Dutch, and American oysters. Six oysters, or the gills of six oysters, were analysed in each case with the following results:—

Six Oysters	Weight of Iron found in mgrme.		
	French	Dutch	American
Gills	0·6	0·4	2·3
Bodies minus gills	1·2	1·5	1·7
Weight of Ash of Gills	0·1880	0·0217	0·0294
„ „ of bodies minus gills	0·5980	0·1125	0·1240
% Iron on ash. Gills	0·32	1·85	7·82
„ „ Bodies minus gills	0·20	1·33	1·37
Ratio of Iron in gills to Iron in rest of body.			
Calculated per oyster	1 : 2	1 : 3·75	1 : 0·74
„ on ash	1·6 : 1	1 : 4·1	5·7 : 1

From these figures it is evident that the gills of the green French oysters do not contain an excessive quantity of iron such as might account for their colour. Calculated per oyster the gills contain less iron than the rest of the body, except in the American oyster; calculated as a percentage on the ash the reverse is the case. The proportionate quantity of iron in the gills as compared with the rest of the body is somewhat greater in the French oysters than in the Dutch, but much less than in the American.

Clearly, therefore, there is no connection between the green colour and the quantity of iron present. This result is quite in accord with Ray Lankester's observation that his 'marennin' is free from iron as well as from copper.

Both the gills and bodies of oysters contain a small quantity of iron, which is evidently normally present, the gills containing a somewhat larger amount in proportion to the total quantity of mineral matter present.

Finally, the total iron in a variety of oysters was determined in order to ascertain the normal quantity present. These data, which are tabulated below, show a fairly constant proportion of iron per oyster, from 0·15 to 0·36 mgrme., or from 0·18 to 0·65 per cent. on the ash.

Total Iron present in Oysters.

Variety of Oyster	Number Analysed	Total Iron grme.	Weight of Ash	Mgrme. Iron per Oyster	Percentage Iron on Ash
Huîtres de Marennes . .	6	0·0018	0·7860	0·30	0·23
Dutch . . .	6	0·0009	0·1393	0·15	0·65
American . .	5	0·0018	0·2791	0·36	0·64
Colne . . .	10	0·0020	1·0938	0·20	0·18
Deep Sea . .	2	0·0064	1·5017	0·32	0·43
Falmouth . .	6	0·0016	0·4534	0·27	0 35

In considering the variations in quantity, the very small amounts of metal present must be borne in mind.

It may be added that although Carazzi has attributed the green colour of French oysters to iron taken up from the mud of the oyster-park or 'claire,' experiments on feeding oysters with very dilute solutions of iron salts (0·02 to 0·01 per cent.) carried on in conjunction with Professor Herdman produced no green colouration whatever. The only result was a certain amount of 'browning' throughout the oyster, the gills being no more affected than the rest of the body. More recently Carazzi has shown that oysters fed with similar dilute iron solutions acquire a pale yellowish colour in certain parts (branchial epithelium and the œsophageal mucous membrane), and that in these parts microscopic tests show the presence of granules of iron. The actual meaning of these results can hardly be recognised without quantitative data.

The Presence of Copper in Oysters.—Fredericq has shown that a certain small amount of copper is present normally in the hæmocyanin of the blood of crustaceans and molluscs. The quantity thus present in oysters of different origin is fairly constant as shown in the following table: it varies from 0·25 to 0·66 mgrme. per oyster, or from 0·30 to 1·18 per cent. on the ash.

Variety of Oyster	Number Analysed	Total Copper grme.	Weight of Ash	Mgrme. Copper per Oyster	Percentage Copper on Ash
'Huîtres de Marennes' . .	6	0·0024	0·7860	0·40	0·30
Dutch . . .	6	0·0015	0·1393	0·25	1·08
American . .	5	0·0033	0·2791	0·66	1·18
Colne . . .	10	0·0036	1·0938	0·36	0·33
Deep Sea . .	2	0·0069	1·5017	0 34	0·46

0·4 mgrme. per oyster may be taken as an average, a quantity slightly greater than the average iron (0·26 mgrme.). The calculated percentages on the ash show greater variations, due to the very considerable differences in the total quantities of mineral salts present, and it is probably to this last factor that the popularly recorded differences in taste of the various kinds of oysters is really due. Certainly the minute quantities of copper and iron present cannot account for them.

The copper was also determined in the gills and in the bodies minu gills of French, Dutch, and American oysters with the following results :—

Determination of Copper.

Six Oysters	French 'Huîtres de Marennes'	Dutch	American
Gills only . . .	Trace	0·8	1·7
Bodies minus gills .	1·4 mgrme.	1·4	3·3

These data show conclusively that the green colour of the gills of French oysters is also in no way connected with the copper present.

Quantities of copper greater than those recorded point to abnormal conditions. Such have been found to occur with certain Falmouth oysters and in an especially interesting manner with the green leucocytosis of American and Fleetwood oysters—the diseased condition referred to above.

Falmouth Oysters.—The presence of relatively large quantities of copper in Falmouth and other Cornish oysters has been repeatedly associated with their bluish-green colour. Dr. T. E. Thorpe[1] states that these oysters, the colour of which, both in character and distribution, is quite different from that of the Marennes oysters, contain on the average about 1·3 mgrme. of copper per oyster. This large proportion is, Dr. Thorpe says, 'obviously caused by the mechanical retention of cupriferous particles.' On relaying they lose their colour, and the quantity of copper present becomes normal, 0·4 mgrme. per oyster.

Six Falmouth oysters, the bodies of two of which were of a distinct arsenic-green colour, were dried at 100° C., and then digested with water and subsequently with dilute hydrochloric acid. The extract contained about half the total copper present, showing that the metal is partially, at any rate, mechanically retained on or in the body of the oyster, probably as a basic carbonate.

The analytical results were as follows :—

Six Oysters	Copper	Iron	Weight of Ash	Mgrme. Copper per Oyster	Mgrme. Iron per Oyster	Per cent. Copper on Ash	Per cent. Iron on Ash
Extract with diute acid .	0·0097	0·0024	0·2272	1·62	0·40	4·22	1·06
Oysters . .	0·0114	0·0016	0·4534	1·90	0·27	2·51	0·35
Total . .	0·0211	0·0040	0·6806	3·52	0·67	3·10	0·59

The total copper present is almost nine times the normal quantity, and about half of this is easily removed by dilute acid. It is quite likely that the remainder is partially or wholly simply entangled in the food passages of the oyster, and that the green colour may be due to some other cause than this mechanically retained copper, as suggested by Herdman.[2] Mr. G. C. Bourne, indeed, regards it as due, in some Falmouth oysters, to a green desmid upon which the oysters feed in quantity.[3]

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[1] *Nature*, 1896, p. 107.

[2] *Ibid.*, 1897, p. 366.

[3] See Note by Mr. Bourne below, p. 569.

The occurrence of copper under such conditions is due to the locality, and may quite possibly attain injurious proportions, for the oysters were obtained from a creek which is locally supposed to bring down copper, and the mud of which was found by Thorpe to contain 0·148 per cent. of copper. Normal sea-water contains such an excessively small quantity of copper that it was not found possible to detect its presence, even electrolytically, in a litre of sea-water, after concentration.

The *green leucocytosis* already referred to was first noticed by Herdman and Boyce in American oysters which had been relaid near Fleetwood. The colour manifests itself in patches and streaks of pale green on the mantle, in engorgements of the blood vessels and in masses of green coloured leucocytes in the heart. The leucocytes are apparently all amœboid wandering cells, comparable to the colourless corpuscles of the blood of higher animals, and the colouration coincides with their distribution.

The six greenest and six whitest of 120 of these oysters were chosen for analysis; also a quantity of the greenest portions of the greenest oysters was selected from another batch, and compared with the corresponding portions of the whitest oysters. The iron was not determined in the latter comparison, owing to contamination of metal in the cutting.

The following were the results obtained :—

Oysters	Copper	Iron	Ash	Mgrme. Copper per Oyster	Mgrme. Iron per Oyster	Per cent. Copper on Ash	Per cent. Iron on Ash
Green . .	0·0158	0·0091	1·1450	2·63	1·52	1·38	0·79
White . .	0·0042	0·0036	1·0948	0·70	0·60	0·38	0·33
Greenest parts	0·0033	—	0·0780	—		4·23	—
Whitest parts	0·0009	—	0·0452	—		1·99	—

The excessive quantity of copper in the selected green oysters is 3·75 times that in the white calculated per oyster, and 3·63 times calculated on the ash. In the selected parts the total copper present calculated on the ash is high in both cases, and the green parts again show a marked excess in the proportion of 2·1 to 1. The copper and iron in the white specimens are about normal, but the increased quantity of iron in the green is marked, being 2·5 times that of the former. Still there is relatively a large excess of copper as compared with iron in the green oysters, as is evident from the analyses, the ratio being 1·1 : 1 for the white and 1·8 : 1 for the green.

It is to be concluded, therefore, that the green colour of these oysters is coincident with the distribution of the excessive quantity of copper present, and that the copper is in consequence to be regarded as the cause of the colour. The histo-chemical investigations of Boyce and Herdman have amply confirmed this conclusion.

Further, this leucocytosis is not accompanied by a mere redistribution of copper, but by an absolute increase of the amount present in the body.

The deposition of copper in this manner is regarded by Boyce and Herdman 'as a degenerative reaction, due to a disturbed metabolism, whereby the normal copper of the hæmocyanin, which is probably passing through the body in minute amounts, ceases to be removed, and so becomes stored up in certain cells.' The change is comparable in kind to the accumulation of iron in pernicious anæmia.

The increased quantity of iron present may also be due to abnormal conditions of life, but a more accurate localisation of the normal iron of the oyster is necessary before this can be decided.

This green leucocytosis has been observed by Herdman and Boyce in other oysters, including those of Falmouth, and it is likely to be the real cause of their colour; a colour therefore due to copper as previously supposed, but accompanied by a diseased condition. Whether the presence of copper in the water facilitates in any way the development of the disease has not been determined; experiments made on keeping oysters in very dilute saline copper solutions give no affirmative results beyond a certain amount of post-mortem green staining.

Manganese was found to be present in several of the varieties of oysters analysed. Its detection is readily effected in the electrolytic method of analysis as it separates at the anode as peroxide. Colne oysters contained 0·14 mgrme. per oyster—a rather smaller quantity than the iron found.

Note *added by* Mr. G. C. BOURNE *in September* 1898.

In 1890 I examined a large number of green Falmouth oysters, all of which exhibited the green leucocytosis subsequently described by Professor Herdman. I repeatedly tested the masses of pale-green amœboid cells taken from the gills for copper, but I failed to convince myself of its presence, though I once or twice got indications of the characteristic reactions.

On the other hand, I found large numbers of desmids in the alimentary tract, and was inclined to attribute the 'greening' to their presence. Having left Plymouth whilst my investigations were in progress I was unable to continue them, but I can confirm all that Professor Herdman states on the subject of green leucocytosis.

Bird Migration in Great Britain and Ireland.—Interim Report of the Committee, consisting of Professor NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Mr. JOHN A. HARVIE-BROWN, Mr. R. M. BARRINGTON, Rev. E. PONSONBY KNUBLEY, *and* Dr. H. O. FORBES, *appointed to work out the details of the Observations of the Migration of Birds at Lighthouses and Lightships*, 1880–87.

YOUR Committee have much pleasure in reporting that Mr. William Eagle Clarke, since his recovery from his serious illness in 1897, has been able to make very considerable progress in extension of his very admirable report read at Liverpool in 1896.

His work in 1898 has consisted in collecting all the serial literature and the Transactions of Societies in evidence since the commencement of the inquiry in 1880, for the purpose of supplementing the data relating to species, and he has succeeded in adding ten thousand records of great value to the Lighthouse data.

It is further his intention this autumn to commence, from the collected material in notes and the schedules, a history of each species in connection with its migration, and to give statistics concerning the dates of arrival and departure, and the routes followed.

To work out these details in a satisfactory manner will occupy two or three years. Your Committee are therefore of opinion that no good results would follow in presenting an incomplete report of the work done up to this time, and they respectfully request reappointment.

Index Animalium.—Report of a Committee, consisting of Sir W. H. FLOWER (*Chairman*), Mr. P. L. SCLATER, Dr. H. WOODWARD, Rev. T. R. R. STEBBING, Mr. R. MACLACHLAN, Mr. W. E. HOYLE, *and* Mr. F. A. BATHER (*Secretary*), *appointed to superintend the Compilation of an Index Animalium.*

BY 'Index Animalium' is meant an index to the original place of publication of every name, whether valid or invalid, that has ever been applied as the generic or specific denomination of an animal, recent or fossil. It may be repeated that the Committee has decided to deal first with the names occurring in literature published from 1758 to 1800 inclusive. The examination of this literature has been carried on as before by Mr. C. Davies Sherborn at the Natural History Museum. He reports as follows :—

'Considerable and satisfactory progress has been made during the year ending June 1898. No less than 2,434 volumes and tracts have been examined and indexed, and from these about 5,000 entries have been obtained. This, no doubt, seems a small proportion, but it must be remembered that all the more important works have already been dealt with. There now remain about 3,500 volumes and tracts dealing with zoology, and published before 1800, to be seen : 1,300 of these are not to be found in this country, and have therefore been ordered and are slowly coming in. As most of these 3,500 publications are unimportant it is hoped that in another two years the literature of 1758–1800 will have been so far sifted as to allow the discussion of the question of printing.

'The final alphabetical sorting of slips for 1758–1800 has been begun, but this in no way interferes with the reference series under genera, as it will be remembered that these slips are all in duplicate.'

The following reports on dates of publication of books have been published by Mr. Sherborn during the year :—

Note on the dates of the Zoology of the 'Beagle.' 'Annals and Mag. Nat. Hist.' [6], xx., November 1897.

Lacépède's Tableaux . . . des Mammifères et des Oiseaux, 1799. 'Natural Science,' December 1897.

Note on Martyn's 'Psyche,' 1797. 'Annals and Mag. Nat. Hist. [7], i., January 1898.

The Committee gratefully acknowledges expressions of sympathy from the Linnean, Geological, and Entomological Societies of London. Its more hearty thanks are due to the Royal Society and the Zoological Society, whose pecuniary aid has enabled many rare books to be purchased, and will make the task of hunting for the remainder comparatively easy.

The help obtained from the sources just mentioned is not enough to secure the services of the compiler, and the Committee therefore asks for a renewal of the grant of 100*l.*, and recommends its own reappointment, with Dr. H. Woodward as Chairman in place of Sir William Flower, who retires from the Committee.

Caves in the Malay Peninsula.—Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Mr. H. N. RIDLEY (*Secretary*), Dr. R. HANITSCH, Mr. CLEMENT REID, *and* Mr. A. RUSSEL WALLACE, *appointed to explore certain caves in the Malay Peninsula, and to collect their living and extinct Fauna.*

THE Committee have received from Mr. Ridley the annexed report on his exploration of the caves at Selangor. Several cases of specimens of recent animals found in these caves, and of masses of stalagmite containing bones, have been received from him; but the examination has been somewhat disappointing.

It was thought that the living fauna of an extensive series of caves within the tropics might be a highly specialised one, for near the equator, in all probability, climatic changes have been slight, and abundance of time has passed in which evolution could work. Caves in temperate regions, on the other hand, have been subjected to the cold of the Glacial Period, and since that period the lapse of time has been insufficient to allow of the evolution of an extensive cave fauna. The hope of such discoveries was, however, completely disappointed, for, with the doubtful exception of the cave snake which lives on bats, there is an entire absence of a true cave fauna in the caverns explored. Neither blind, large-eyed, nor white animals, such as inhabit caves in temperate regions, were found. It has been suggested that the absence of a special cave fauna may be due to the small extent of the caves explored in comparison to the size of the Adelberg and great mammoth caves of America, and the presence of the open shafts from above, down which living insects and other creatures would be continually falling, and thus prevent specialisations. But it may possibly be thus explained.

Cave animals in temperate regions are forms which have become adapted to a climate unvarying through night and day and through winter and summer. They are no longer fitted, therefore, for the external conditions, and will probably conform more and more to the conditions under which they live. The same discordance between the internal and external conditions will make any interchange of species a comparatively rare thing. A tropical cave, on the other hand, in a moist unvarying climate like that of Selangor, exhibits conditions only differing from those outside in the absence of light. There must, therefore, be a constant interchange between the internal and the external fauna. Most nocturnal species could inhabit the caves, if food is there to be found, and the cave animals might readily stray outside and again learn to hide during the daytime. This free interchange has probably prevented the development of any peculiar cave fauna at Selangor; though in a less rainy part of the tropics, where there is an alternation of seasons, or of day and night temperature, such a fauna will probably be found. The exploration of such a cave might lead to valuable results.

Climatic conditions may be responsible in great measure for the absence also of traces of man in or beneath the stalagmitic floor of the caves at Selangor. Man in such a climate would not require the shelter of a cave: he would merely need a rock shelter projecting sufficiently to keep off the rain. Such rock shelters are more likely to yield anthropological results than is the exploration of the interior of any caves.

The absence of bones in the cave earth beneath the stalagmite is singular, for Mr. Ridley's observations show that such bones were once there, though they have almost entirely decayed. Whether this also is due to the climatic conditions, the Committee cannot say; but as the further examination of these caves, where the destruction has been so complete, is not likely to lead to any discovery of great importance, the Committee do not ask to be re-appointed: at all events, unless a favourable opportunity occurs for the scientific exploration of the much larger caves than those of Selangor which are known to exist in the interior of the Malay Peninsula, farther to the north.

APPENDIX.

Report by Mr. H. N. Ridley.

The limestone rocks which contain the caves described in this report form a roughly shaped mass of large size, situated at a distance of seven miles to the north-west of Kwala Lumpur, the capital town of the native State of Selangor, in the Malay Peninsula.

On both flanks of the great central granite backbone of the Malay Peninsula occur, at irregular intervals, detached masses of similar limestone of various sizes, of which this is, as far as I know, the most southern portion. Most of these limestone hills occur at some little distance from the granite hills, but it is, I think, pretty certain that they were formerly in absolute contact with them, and that they originally formed a continuous chain running up to the Lankawi Islands, off the coast of Siam, which consist almost entirely of exactly similar rocks, and into the mainland of Siam itself. Furthermore, there is a very marked connection between the flora of the top of the Selangor rocks and that of Lankawi. It is entirely different from that of the granite hills of Selangor, and even from that of the plain country at the foot of the limestone, but reappears in the Kota Glanggi Hills in Pahang, on the east side of the main chain. I believe that, when thoroughly examined, the whole of this group of hills will be found to bear the same flora, and probably also the same fauna, as that, not only of the limestones of Siam, but also of those of Borneo, showing a former connection between these places in the form of a continuous stratum, of which the greater part has been swept away by denudation, at least in the south of the Malay Peninsula. It must be remembered that at present practically no geological researches have been made in the Malay Peninsula, or to any great extent even in Borneo or Siam, and in the peninsula even much geographical exploration needs to be made.

The rock itself is very similar throughout, a white, more rarely blue, crystalline limestone, very hard in texture. The whole mass of hills consists of vertical cliffs, except where denudation has thrown down piles of talus, and these and the upper parts of the cliffs are covered with a dense vegetation of shrubs and trees, often of considerable size. The top of the mass is split up into ridges with broken cliffs, so that ascent to the upper part is in most places quite impossible; and the accessible spots on the top are of very restricted area, so that exploration of the upper parts of the ridge is very difficult. It is on these upper ridges that the wild goat (*Nemorhœdus*) is said to occur, but I could find no trace of its presence. It is well known, however, in similar localities in Perak and Pahang, as well as Tenasserim and Sumatra.

The whole of the block is perforated with caves of various sizes and at various altitudes, as well as by vertical shafts leading to extensive caverns deep in the rock. The greater number of those that are known have never been thoroughly explored, owing to the difficulty of getting about in them, and a large number must occur in the eastern and northern sides, which have hardly, if ever, been visited.

The caves specially examined were those on the south-west side of the rock. Of these one known commonly as the Dark Cave opens about seventy feet above the base of the cliff, and is accessible by a track leading up a large mass of talus, now thickly covered with dense forest. The others opened at, or near, the base of the cliff, and were therefore considered more likely to produce human and animal remains than the less accessible upper ones. Many smaller caves at various points were more or less cursorily examined; but as they showed no signs of old cave floors, nor any probability of their being productive in any way of anything of interest, no extended researches were made in them.

Most of the caves contain stalactites, often of large size, but as it was evident that the rate of deposit varied in different parts of the caves it was quite impossible to conjecture the size of the floors in this way.[1] It was noticed, however, that in one cave considerably higher than the Dark Cave the deposit was much more rapid, the water passing through the cave depositing its lime on the floor in various forms. In one spot, where the water ran in a succession of wavelets over a sloping surface, the whole of the floor was covered with lime deposit in the form of waves. Here, therefore, the deposit was of rapid growth.

In most of the darker caves the floor was covered with a layer, six or more feet deep, of bat-guano, mixed with a little soil, derived from washings down from the open shafts, and more or less impregnated with lime. In some cases crusts of calcareous mud were thus formed, which broke through on being stepped on. Similar deposits, hardened into rock of a tough nature, were found outside the mouth of the Dark Cave.

Here and there were found layers of stalagmite alternated with the bat-dung, and forming an exceedingly hard, tough rock. The immense accumulation of the bat-guano testified to the great age of some parts of the caves at least. In one spot, beneath a bat's roosting-place, was a cone of this deposit fully twelve feet in height. Beneath the shafts were large accumulations of soil, fallen rocks and trees, and several times bones of monkeys were found there, the animals having fallen from the top and been killed.

The Dark Cave.

This cave opens towards the south, on the face of the cliff, and runs in a N.N.E. direction. The mouth is twelve yards in width and of a considerable height. About fifty yards from the mouth is a shaft communicating with the top of the cliff, after which the passage runs in a more easterly direction to a larger open shaft, 374 yards from the mouth, whence a passage leads in a direction of E.N.E. for 484 yards, the total length being thus 858 yards. The height of the cave varies from twenty feet, or thereabouts, to about seventy feet, but it was impossible to measure, as the sides are very steep. This cave contains a considerable

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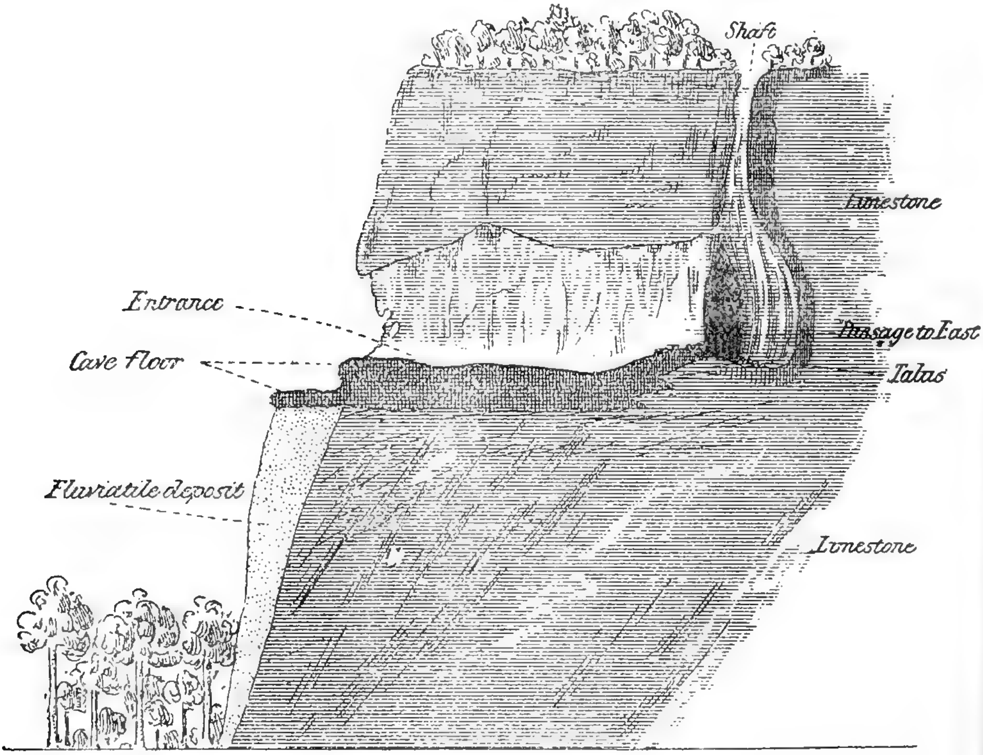
[1] The Malays are well aware of the growth of stalagmites, but are under the impression that if one is transferred to a garden it will grow equally well.

variety of animal life, especially in the furthest portion. Bats, chiefly fruit bats (*Cynopterus*), toads (*Bufo asper*), the cave snake, myriapods, insects, arachnida, and mollusca are abundant. The floor is thickly covered with bat-dung to a great depth, and, except in a few spots, but little calcareous deposit is being formed.

At the mouth of the cave the stalagmite floor comes to the surface, and drops abruptly for a height of four feet. It consists largely of fallen blocks of stalactite cemented by stalagmite. In front of this is a small plateau, about twenty-three feet long, sloping to the edge of the cliff. This is covered with a layer of soil, three feet deep, containing a few scraps of Chinese pottery and fragments of ox-bones, and below this is an older cave floor, consisting of a hard, tough rock of soil and lime combined, full of bones of bats, and a few shells resembling those to be found in or around the caves.

FIG. 1.—Diagram of Section at Mouth of Dark Cave.



As bat-bones in such abundance are only to be found in the darkest parts of the caves, and at some distance from its mouth, this shows that the cave extended formerly to the edge of the cliff, and probably far beyond. The original entrance has evidently been quite denuded away, and had any human beings tenanted the cave at that period they would probably have left their traces in the lighter cave mouth, which must have disappeared long ago.

On descending the cliff to a small ledge about twenty feet below the stratum containing bat-bones, I found a very small cavern about six feet high, the walls of which were formed of a fluviatile deposit of yellow mud, with bits of carbonate of lime. This deposit was traced to the foot of the cliff, filling up a V-shaped cleft. It was hard and tough, indeed, nearly as hard as the surrounding limestone. Unfortunately, this rock, the oldest deposit of all, contained no traces of any organic remains, probably because the original mud was not suitable as a preserving medium.

In the cavern were also the remains of cave floors of later date, containing bones of bats and shells of terrestrial molluscs, such as commonly occur round the caves, and loose on the floor was found the internal cast of one of these shells in carbonate of lime.

The dark cave, then, appears to have originally had a large stream flowing out of it at a time when the surrounding country was at a very much higher level than it is at present, and this stream deposited a very large mass of mud, now converted into rock. Gradually it ceased to flow, and more lime was deposited on the surface till the floor consisted almost entirely of carbonate of lime, the cave being, as at present, tenanted by myriads of bats. The final history has been one of steady denudation, the front of the rock being worn away and the mouth of the cave retreating. There is nothing to show what amount of denudation there has been on this cliff face, but the height of the stream deposit shows that it must have flowed out of the cave fully fifty feet above the level of the surrounding country.

On about the same level, and close to the Dark Cave, is one known as the Cathedral Cave: it consists of an immense arch leading to a large shaft, perfectly open, and full of small trees and shrubs. Though remarkable from its picturesque and striking beauty, it seemed unlikely to produce any interesting results in the matter of geology; so I examined it but cursorily.

The Quarry Cave.

The next cave examined was a smaller cave known as the Quarry Cave. It opens on the eastern side of the rocks, at the foot of the cliff, about a quarter of a mile from the Dark Cave. It is a low cave of no great size, traversed near the mouth by a stream, dry at the time of my last visit, but which I have reason to believe is the outlet of a stream which crosses the Dark Cave at one point at the foot of the first shaft, and descends in a small steep passage.

The present mouth of the cave is a narrow opening about seven feet high, but it is clear that at one time it was very much larger, the mouth having been nearly closed by an immense mass of stalagmite, which will probably in time close it altogether. The stream, which formerly ran out through an opening, at present blocked by stalagmite, now finds its way out beneath the main mass.

The floor up to the original cave-opening is a mass of stalagmite mixed with mud containing a few remains of bats and shells. An excavation was made in the stream-bed to some depth. The soil consisted of yellow mud, rather stiff and clayey, with fallen fragments from the roof. No trace of any animal or vegetable remains could be seen, not even bones of bats or shells, which were excessively abundant on the present surface of the stalagmite. The stream is probably too rapid to allow of any animal remains to be preserved, nor does the cave appear to have been ever occupied by man.

Bats in myriads tenant the cave, chiefly, if not exclusively, *Cynopterus Lucasi*, and I took no less than five cave snakes here; an unusual number for so small a cave.

The Sakai Cave.

A good way further to the east, along the same face, are several other caves, one of which is known as the Sakai Cave, on account of there being the remains of occupation by the wild tribes, in the form of palm-leaf shelters and rough charcoal drawings on the walls.

It was especially investigated as being likely to contain traces of occupation by earlier races. It is quite a small cavern with a rather wide mouth. Remains of old cave floors are to be seen all round on both sides, consisting of an exceedingly hard brown rock much impregnated with lime, and full of angular pieces of limestone, and containing also bones of bats and shells of mollusca.

The greater part of the floor has, however, been broken down by a stream which ran across the cave and out of the mouth, filling up the entrance with soil for a considerable depth. The stream has evidently long been dry, and it is on the soil at the mouth that the Sakais have encamped. Two parallel trenches were dug across the cave to a depth of over six feet. In the one nearest to the mouth the soil was found to be a dark red earth containing much iron, and in the upper part a splinter of bone and a rounded stone, evidently brought from the river, and probably used to support a cooking-pot, were found. Below this no trace of animal or vegetable remains could be seen. The inner trench showed in section a layer, of about a foot in depth, of brown soil, containing a small quantity of charcoal scattered about, below which was a white, granular, calcareous sand, partly agglutinated into irregular lumps, but quite barren of any organic remains. It contained much mica. Mica, indeed, appears in a good many of these cave stream-beds, and also in the soil on the upper part of the cliffs. It is evidently derived from the granite hills (now denuded away) which were formerly in contact with the limestone ridge, the present hills being separated from the limestone by a valley drained by several streams.

It seems that the wild tribes seldom use any of these caves, and have only done so comparatively lately. I did not see any trace of their having been here since my last visit six months previously.

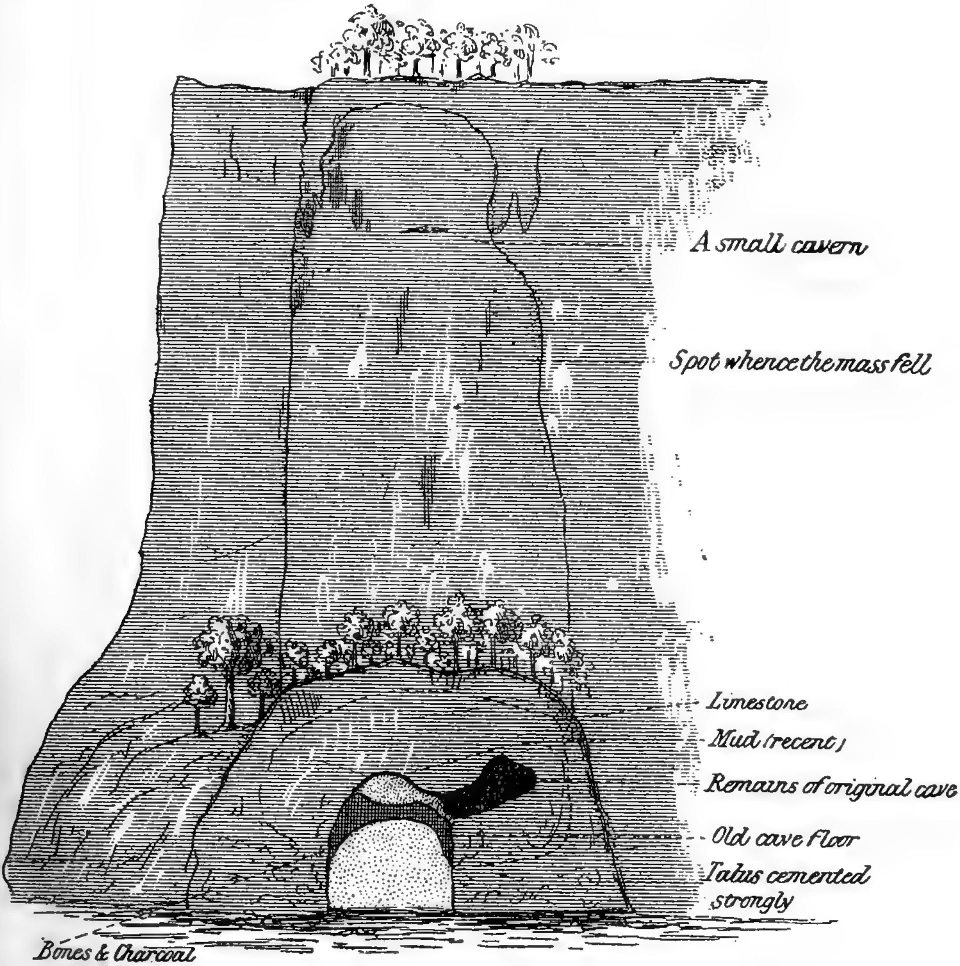
I attempted to examine the lower part of the cave floors above alluded to, but they were so covered with fallen masses of limestone from the cliff-face that I was unable to get at them.

The Fallen Cave.

Between the Quarry Cave and the Dark Cave, and only about fifty yards from the former, was a very small cave, only sixty-six feet long, in a vast mass of *débris* fallen from the cliff, which is here quite vertical. The talus is covered with trees of fairly large size, but the face from which the mass fell is clearly distinguishable even yet. The cave did not appear likely to be one of any interest, but on inspecting it I found a cave floor about six feet above the present floor. This floor sloped to the north, and there was little space above it. An examination showed that it contained charcoal, and further excavation produced several bones, chiefly fragments of ribs, which had apparently been used as food by some race of men. They were often much impregnated with iron, and the medullary spaces lined with crystals of carbonate of lime. The vertebra of an ape (?)

and bats' bones were also found. The rock in which they were imbedded was tough and hard, apparently a mud mixed with bits of chalky limestone and much oxide of iron in the form of veins and nodules. This portion of the floor was entirely in contact with the cliff wall. The rest of the floor was more muddy and softer. A very considerable portion of the original floor had been denuded away by water. What appeared to have been other bones lay scattered all through this muddy deposit, but they were so much altered that they were quite indeterminable. Iron had been deposited on them, and the bones themselves eventually corroded away, their casts filled with crystals of carbonate of lime, and that, again, sometimes apparently replaced by iron oxide.

FIG. 2.—Diagram of Section of Fallen Cave (overturned).



It appears that this cavern had fallen from the cliff, and the rock containing it was lying on its side. In one direction a portion of the original cavern could be seen, but it was inaccessible, being partly filled with a soft mud which it was impossible to walk on. The original form and position of the cave were indeterminable, owing to the crushing in of the sides and inversion of the whole mass. That it must have been of considerable antiquity there could be little doubt.

Present Fauna of the Caves.

Mammalia.—The most abundant tenants of the caves are the bats. In some caves, such as the Quarry Cave, these seemed to be exclusively fruit-bats (*Cynopterus*); in another there were thousands of two small insectivorous species (*Rhinolophus affinis*, and *R. minor*). The bats live in the darkest parts of the caves, the ground beneath their roosting-places being often covered with their bones, of which those of the wings seemed to be the most durable.

The larger mammals can hardly be said to be denizens of the caves. In the entrances of some of the smaller caverns fresh tracks of tigers, very abundant in the surrounding woods, were to be seen; but they do not, it seems, inhabit the caves regularly, or breed there. Tracks of bears (*Helarctos malayanus*) were seen in one rather open cave, and with them were those of deer.

Civet cats (*Viverra*, spp.) certainly use the caves a good deal, as not only were their tracks seen, but in many parts of the darkest caves germinated coffee beans were to be seen deposited here in the dung of these animals, but neither the animals themselves nor their bones were found. In one or two caves tracks and burrows of what was evidently one of the porcupines were met with, probably the brush-tailed porcupine (*Atherura*), which I have seen in the caves of Kota Glanggi, in Pahang. No signs of any other rodents were seen in or near the caves, and though I set traps for them I never caught any.

The surrounding forest contains a large assortment of the bigger wild beasts, including tiger, bear, wild-ox, pig, muntjac, deer, and elephant, and the absence of any bones of these animals in the caves is worth noting by palæontologists as showing that a district may be rich in large animals, although there may be no remains of them preserved in the caves.

In a tropical region primitive man seldom utilises caves except as a temporary refuge from rain, or, at a later stage of civilisation, as a temple. He prefers here to live either in tree houses or in buildings supported on high poles, so as to avoid risk from the nocturnal attacks of tigers or the incursions of snakes, scorpions, or other such vermin, and with the aid of leaves of palms or screw-pines he can protect himself against rain, and has no fear of cold or snow, which the early European races had to guard against.

A large proportion of the bones of animals found in European caverns were introduced by hyenas and other beasts of prey. The hyena is absent from this region, and the large carnivores do not carry their prey to any distance to devour it, so that there is little chance of the bones of their victims being found in caves.

A certain number of the bones in European caverns again are accounted for by the animals having fallen through openings at the top. In these cases it is evident that the upper surface of the limestone whence the animals fell must have been plain, open country, or, at all events, well suited for the existence of large animals. This is not the case here. The larger animals could hardly ascend the cliffs at all, and would have much difficulty in moving about when once there. Monkeys, however, which do frequent the woods clothing the upper part of the hills, not seldom fall into the shafts, and their bones may often be seen lying at the foot.

The immense abundance of bat remains in the floors is very striking in comparison with their rarity in the European and other caves. Fruit-bats are very characteristic of high jungle, as they require so great an amount of fruiting trees, and the discovery of their bones in any quantity in any deposit would be *primâ facie* evidence of the surrounding country having been, at the time of their deposition, densely wooded.

Reptilia.

The cave-snake (*Coluber tæniurus*) is common in all the darker caves where bats are abundant. I have to thank Mr. Boulenger for its identification. According to the 'Catalogue of Ophidia,' it occurs also in Darjiling, Sumatra, Borneo, and China. But in the description in the work above referred to the colouring differs considerably from that of the cave snake. Thus it is described as being 'grey brown or olive above; head and nape uniform; anterior part of the back with black transverse lines or network; posterior part with a pale vertebral stripe between two broad black ones; belly yellowish anteriorly, greyish posteriorly; a black stripe along each side of the posterior part of the belly and along each side of the tail, separated from the upper lateral stripe by a whitish stripe.'

Now of the cave-snake no part can be called even grey brown, still less olive, the upper parts being of a pale, ochreous colour. The head is light bluish grey, with a black line running through each eye. There is no trace of any black transverse lines or network. The colouring of all the snakes I have seen (eight in number) was exactly similar.

These differences in colouring may appear very trivial, but to the animal itself they are of no small importance. The cave-snake never, apparently, leaves the caves, and very rarely even comes into any part of the mouth where there is much light. Indeed, it is usually to be found in the darkest parts of the caverns, where it rests on ledges of rock looking out for its prey, the bats.

Its colouring is so exactly similar to that of the cave walls—a pale yellowish ochre—that it is very difficult to see, and the largest I ever found (six feet seven inches in length) I had passed by without noticing, though I was looking for snakes. Not only is the general body colour that of the cave walls, but the grey lines darkening into black towards the tail add to the illusion, exactly resembling the shadow of a crack or ridge, such as is commonly to be seen on the walls. Upon the black mud of the floor the snake is tolerably conspicuous, but when lying on a ledge, or reared erect along a wall, it is exceedingly easily overlooked. No colouring could be more suited to its surroundings. Were it, however, to leave the caves and live in the jungle like other snakes, it would be as conspicuous as possible, as it then would appear by contrast almost pure white.

I can find no account of the habits of the species elsewhere, nor whether this peculiarly coloured form has elsewhere been seen; but it seems of the greatest interest to find a snake so peculiarly and beautifully adapted to such strange surroundings.

It seems to feed exclusively on bats. Twice I have seen it just fallen from a rock-ledge with a bat in its mouth, seized as the bats, disturbed by our torches, flew wildly about the cavern. Cast skins and skeletons were several times found in the caves. One of the latter was partly cemented to a stalagmite by a deposit of lime, and was in process of being fossilised.

The only other reptile seen in the caves was a 'white lizard,' probably one of the *Geckonidæ*, seen by one of a party with me in the darkest part of the Dark Cave. It escaped, and no others were seen.

Batrachia.

Bufo asper.—This toad occurred in all the darker parts of all the caves, and some of the specimens were of very large size. It was chiefly met with in damp spots.

Insecta.

There are a considerable number of insects to be found in the caves of which specimens were collected and forwarded to the British Museum for examination. Unfortunately, one of the cases of spirit specimens sent in February last was lost in transit to Europe, but later I re-collected most of the animals then obtained. *Hymenoptera* were represented by a species of black ant (family *Poneridæ*) found in the furthest part of the Dark Cave. *Coleoptera.*—A few minute beetles were seen. *Diptera.*—A very small fly (fam. *Chironomidæ, gen. et sp. nov.*, closely allied to *Ceratopogon*) was exceedingly abundant in places where bats were plentiful, so much so as to be quite a nuisance. It apparently bred in the bat-guano. One or more species of bug (*Hemiptera*) occurred in and about the dry guano. *Neuroptera.*—A single specimen of a very transparent, fragile ant-lion (*Myrmecœlurus* sp.) was obtained in the Dark Cave near the nest of ants, and the wing of another was seen in the mouth of a centipede. *Orthoptera.*—A curious brown species (fam. *Stenopelmatidæ; Diestrammena, sp. nov.*) occurred in all the dark caves. It had a remarkably hard, chitinous coat, and very long legs and antennæ. It is apparently always wingless, for I saw hundreds of all ages and both sexes, but never saw any with even rudimentary wings. It was very active when disturbed, and at times uttered a feeble chirp. Cockroaches (fam. *Panesthiidæ*) were very common in the dry, powdery guano, which heaved with them when light was thrown upon it.

Arachnida.

A fairly large blackish scorpion (*Chœrilus, sp. nov.*) was caught in the Dark Cave, the only one seen. Several kinds of spiders occurred: one was an ordinary web-spinner; another formed round silken discs attached to the stalactites and walls by the sides, and free at each end, so that the spider could open or draw tight to the rock either end, after the manner of a trap-door. The nest was coated with calcareous mud, so as to resemble a portion of the rock; from it ran strands of silk radiating in every direction. A third spider made silken tunnels, about six inches or more in depth, in the dry guano.

Myriapoda.

The most conspicuous and abundant was a large species of centipede (*Scutigera maculata*) with a banded and spotted body and legs, brown and white, the joints of the legs being sometimes of a violet colour. It lived on the walls of the caves, running with great briskness, and seemed to feed on the cockroaches, ant-lions and other insects. It appeared to be quite harmless, and did not try to bite when caught.

One or two other centipedes were also seen and caught, as well as a small pinkish millipede and a white myriapod, somewhat resembling *Polydesmus*, both of which occurred in damp spots on the ground.

Isopoda.

Woodlice (*Armadillo intermixtus*) were common on the walls.

Mollusca.

Stenogyra tchehelensis was very common, especially where water ran over the rocks. The shells are whitish, the animal dull yellow. It seemed to have a habit of rolling itself in the bat-dung, collecting a ball of it on its shell.

I sought in vain for crustacea in the few pools which appeared to be permanent in the caves. There seemed to be no trace of any animal life in them.

I have excluded from the cave fauna such stray insects, &c., which only occurred in the open shafts or in the mouths of the caves. All the animals above mentioned were met with in perfect darkness, and the greatest number occurred in the furthest part of the Dark Cave, nearly half a mile from the mouth.

Comparison with the Bornean Caves.

The Bornean limestone caves were investigated by Mr. A. H. Everett in 1878 and 1879, and some also by Beccari in 1865, and there are also a few observations on the Limestone and its Caves, by Posewitz ('Borneo: Its Geology and Mineral Resources').

I gather from these papers that the limestone in Borneo is quite identical with that of Selangor. Mr. Everett, however, found encrinites in some part of it, but no fossils have as yet been found in any of the limestone of the Malay Peninsula. The fossils show that the formation is Carboniferous Limestone. The Borneo rocks, again, show traces of sea action at no great distance of time. I can see nothing of this in the Selangor rocks, but, curiously, there is a tradition among the Malays that the sea originally came as far as this, and that the rocks themselves are a portion of a ship turned into stone.

Bones other than those of bats seem to be more abundant in the Borneo caves, but, like those of Selangor, belong to animals still extant in the neighbourhood. It appears, however, from Mr. Everett's paper, that the living cave fauna is a good deal more extensive than that of Selangor, but I do not know of any detailed account of it.

Human remains are more plentiful, and show a rather high state of civilisation. But it must be remembered that the earliest race in the Malay Peninsula of whom we know anything are the Sakais, who are by no means as highly civilised as Dyaks, making no works of art such as pottery, beads or metal-work, and possessing no domestic animal except the dog; and it is highly improbable that the earlier race who used the stone axes commonly found in the peninsula were more highly civilised.

It was to be hoped that remains throwing light on the Stone-age men of the Malay Peninsula might have been found in the caves, but as yet nothing has been found anywhere in the whole peninsula except the axes themselves.

Concluding Remarks.

I would point out, in conclusion, that the number of caves examined by me is small in comparison with the large number scattered over the peninsula. Probably the greater number have never been visited by any European. Few persons here have the time and facilities for making researches of this kind, and fewer still have the knowledge or inclination which would enable them to make observations of value. However, as the country gets more and more opened up and accessible, it may be hoped that more extended researches into the geology may be made by persons resident here.

Canadian Biological Station.—First Report of the Committee consisting of Professor E. E. PRINCE (*Chairman*), Dr. T. WESLEY MILLS, Dr. A. B. MACALLUM, Professor JOHN MACOUN, Professor E. W. MACBRIDE, Mr. W. T. THISELTON-DYER, and Professor D. P. PENHALLOW (*Secretary*), *on the Establishment of a Biological Station in the Gulf of St. Lawrence.*

AT a meeting of the Committee held in March last, it was resolved to approach the Dominion Government with a view to enlisting its co-operation and financial aid in the establishment of a Biological Station in the Gulf of St. Lawrence, which should be devoted primarily to investigations on the nature and the sources of the food of fish, oysters, and lobsters, while it was also hoped that facilities might be afforded whereby the various universities where biological work is carried on could secure opportunities for specially qualified students to conduct scientific investigations. In April a communication was addressed to the Minister of Marine and Fisheries, Hon. Sir L. H. Davies, K.C.M.G., embodying the following recommendations :—

1. That a floating station be established in the Gulf of St. Lawrence for a period of five years.
2. That this station be established first on the southern coast of Prince Edward Island, and that it be moved each year to a new location according to requirements.
3. That the various universities and scientific bodies of Canada should be granted certain privileges with respect to opportunities for qualified investigators as may hereafter be determined.
4. That the scientific work of the station be executed, as far as possible, by experienced investigators connected with our various universities.
5. That while the station remains a Government institution, the administration be vested in a special Board consisting of one or more representatives from the Department of Marine and Fisheries, and one representative from each of the universities represented in support of this petition.
6. That an appropriation of $15,000 be made for this purpose, of which $5,000 shall be applied to construction and outfit, and $10,000 to maintenance for a period of five years.

This communication was presented by the Committee, supported by an important representation from the maritime provinces and from the leading universities of the Dominion.

The request was granted, and an appropriation of $7,000 has been made to meet the cost of construction and outfit and the running expenses for one year. It is the present intention to have all preparations completed in time to commence active work early in the summer of 1899.

The Board of Management as now constituted consists of the following members :—

Professor E. E. PRINCE, Director, Department of Marine and Fisheries.
Professor D. P. PENHALLOW, } McGill University.
Professor E. W. MACBRIDE, }
Professor RAMSAY WRIGHT, Toronto University.
Professor L. W. BAILEY, University of New Brunswick.
Professor A. P. KNIGHT, Queen's University.
Rev. V. A. HUART, Laval University.
—————, Dalhousie University.

Investigations made at the Marine Biological Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. C. BOURNE (*Chairman*), Professor E. RAY LANKESTER (*Secretary*), Professor SYDNEY H. VINES, Mr. A. SEDGWICK, *and* Professor W. F. R. WELDON.

Report of Algological Work. By G. BREBNER.

HAVING had the honour to be appointed to the British Association Table for a month during the current year, I was glad to avail myself of the opportunity to carry on my investigations into the life-history of the Tilopteridaceæ during my Easter holidays.

Although my results were negative, I gained a certain amount of knowledge and experience, which I hope will enable me to prosecute the investigation with more success another year.

The vexed question of fertilisation in certain of the brown sea-weeds is at present attracting a good deal of attention among others in the Tilopteridaceæ, a group in which I am specially interested. In the two best defined genera of that family there seem to be well-differentiated *antheridia* (male organs) and *oogonia* (female organs). At the same time the plants bear what are generally considered to be non-sexual organs, or *sporangia*.

In a paper recently published (see Bristol Naturalists' Society's 'Proceedings,' vol. viii. Pt. II. 1896–97) I suggest that the family should be limited to the two monotypic genera *Haplospora* and *Tilopteris*. In one of these, *Haplospora globosa*, the three kinds of reproductive organs are much more clearly differentiated than in the other, *Tilopteris Mertensii*, in which, owing to their similar position in the frond, it is almost impossible to distinguish the *oogonia* from the *sporangia* unless we may assume that those specimens which bear *antheridia* likewise bear oogonia only. We unfortunately cannot with safety assume this, as I have shown that *Haplospora globosa* may be 'sporo-hermaphrodite.'

Haplospora globosa would be the best species on which to study this question of fertilisation, but the antheridic specimens are so rare in this alga that I had to fall back upon the much less suitable *Tilopteris Mertensii*, which is much more abundant and widely distributed in this country, and also much more frequently antheridic. *T. Mertensii* occurs abundantly at Cumbrae, N.B., but unfortunately antheridic specimens are not common, so, having ascertained that it grows at Plymouth, I thought it advisable to try that locality at Easter. At Plymouth I was not able to secure it in quantity, but through the kindness of the Director of the M.B.A. Laboratory I was able to secure a fair number of plants by dredging at different times off Mount Edgecumbe. It is a distinctly interesting fact that they were practically all antheridic. Mr. A. H. Church, in his interesting paper on Cutleria (The Polymorphy of *Cutleria multifida*, Grev., 'Annals of Botany,' vol. vii. No. 45, March 1898), points out that that plant seems to have what I think might be called *isotherms* of fertilisation; that is to say, the temperature of the sea seems to largely determine the presence of sexual organs and also their power to unite sexually. If he is right, there is an optimum below which fertilisation cannot take place, but undoubted parthenogenesis of the oospheres.

If Mr. Church's views are correct—and they seem well supported by the evidence—then the negative results with regard to *Tilopteris* may be accounted for.

My own results did not differ essentially from those of previous observers. The plants were repeatedly under observation, especially early in the morning, and were frequently seen to discharge both spermatozoids and oospheres; but there was no sign of the latter exercising an attractive influence on the former, as is so easily seen to be the case with such oogamous Phæophyceæ as *Fucus*. Further, the presumptive oospheres were in certain cases extruded under conditions which rendered access of spermatozoids impossible, and yet they germinated freely, giving rise to characteristic young plants of *T. Mertensii* in the course of a month. The conditions of temperature were varied as much as possible, but no other result was obtained, the oospheres under no conditions exercising an attractive influence on the spermatozoids. It is very difficult to keep these rather delicate sea-weeds under continuous microscopic observation in anything like natural conditions; but with improved methods of treatment it is possible positive results may yet be obtained, and it is my intention to renew my attempts at the proper season in the hope that a definite positive result may be reached, for I am inclined to believe in the sexuality of the organs under investigation.

In conclusion I have to tender my best thanks to the Appointing Committee for the privilege of using the British Association Table during the period named.

Report on Nerves of Arenicola, Nereis, &c. By F. W. Gamble, *M.Sc.*

While recently investigating the anatomy of several species of *Arenicola* I discovered in *A. Grubii* certain nerve-cells which, from their size (averaging 65μ in diameter) and their definitely segmental arrangement, differed very markedly from other elements of the cord. Accordingly, when nominated to occupy the Plymouth Table by the British Association Committee, I determined to apply some recent methods to fresh material, and for this purpose selected the methylene-blue method.

In addition to species of *Arenicola* the following genera were tried: *Polynoe, Lepidonotus, Sigalion, Sthenelais, Aphrodite, Halosydna, Nereis, Nephthys, Glycera, Capitella, Terebella, Chætopterus*, and one of two undetermined Sabellids. *Ophryotrocha* and larvæ of *Terebella* and of *Polyophthalmus* were also experimented with.

The method was that of Ehrlich as modified by Allen ('Q.J.M.S.,' 1894), and the stain as fixed by the ammonium molybdate solution (after Bethe's recipe). The preparations were dehydrated and cleared by slow diffusion into xylol or cedar-wood oil. At first I employed an injection of a ·1 per cent. solution of methylene-blue, but I soon found that better results could be obtained by rapidly dissecting out the nervous system and watching the progress of the stain under the microscope. The best temperature for rapid staining of unaltered nerve-fibres is about 65° F., while in passing the preparations through alcohol a low temperature is advisable, otherwise the stain is liable to be washed out.

Nereis, *Polynoe*, and *Halosydna* gave the best results. The elements of the nerve-cord of *Nereis diversicolor*, though delicate, are rapidly stained before the fibres have time to 'bead.' The number and arrangement of the nerve-elements in this species are still occupying my attention. Unfortunately only a couple of specimens of *Halosydna gelatinosa* were obtained during my stay at Plymouth. The somewhat short nervous system, the ease with which it can be exposed, and the stoutness of many of the fibres, are great advantages in dealing with this species.

With regard to the tubicolous Polychæts, my experience agrees with that of other observers. The method that gives excellent results in *Nereis*, at the same time and under the same conditions, fails to stain differentially the elements of the cord in *Arenicola* or *Chætopterus*. Out of a large number of preparations of *Arenicola Grubii* a few only show the course of a small number of nerve-fibres. I hope, however, by modifying the stain to obtain better results than heretofore.

In conclusion, I wish to tender my sincere thanks to Mr. E. J. Allen, the Director of the Plymouth Laboratory, for placing the resources of the laboratory at my disposal, and especially for his kind assistance and advice.

Report on Mr. J. H. WADSWORTH's *collection of material for the Study of the Embryology of Alcyonium. By* Professor S. J. HICKSON, F.R.S.

On arriving at the laboratory on December 31, Mr. Wadsworth found in one tank (which I will call Tank I. in this report) sixteen healthy colonies of Alcyonium, which had been placed there twenty-four hours previously by Mr. Allen. The water in this tank contained a number of embryos in different stages of development up to the stage they reach in twenty-four hours. These were all removed and preserved, some in corrosive sublimate and acetic acid, some in Hermann's fluid, and some in Mix. No. 3 (chloroform, acetic acid, and absolute alcohol). In another tank (Tank II.) there were about sixty colonies, many of which were not in a healthy condition. In the water of this tank there were numerous embryos, some of which were clearly abnormal and unhealthy. Thirty-six of the colonies from this tank were removed to fresh sea-water in Tank III.

During his stay at Plymouth Mr. Wadsworth collected at different times the embryos that were found free in the water of these three tanks, and preserved them in various reagents, noting, in each case, carefully the time that had elapsed since the water was free from embryos.

On January 3 a female colony was placed in a bell jar by itself, a quantity of ripe sperm was added to the water, and Mr. Brown's agitator employed for keeping the water in the bell jar in motion. Some of the embryos shot out by this specimen were preserved ten hours afterwards in the corrosive-acetic mixture, the remainder were isolated and preserved, some on January 5, at 10.30 A.M., in Hermann, others on January 5, at 8.10 P.M., in No. 3 mixture. The use of this method was not, on the whole, satisfactory, as many of the embryos obtained in the last series were clearly moribund; but as some of the oldest embryos of the series were perfectly healthy, and show beautiful karyokinetic figures in the sections, it is probable that renewed experiments with it would be successful.

Another female colony, together with a male colony, were isolated in a bell jar which was allowed to float in one of the tanks. The embryos collected from this were at first healthy, but after twenty hours the water became foul and the embryos died.

These two experiments, to isolate individuals and to endeavour to obtain the exact ages of the embryos and others that were tried, have given me some data, but cannot be said to have been thoroughly satisfactory. Mr. Wadsworth's time during his stay at the laboratory was very largely occupied in collecting and preserving the embryos that were found free in the large tanks, and these have yielded some very fine series, the most successful of which are those preserved in Rabl's fluid and in the No. 3 mixture. Before leaving the laboratory Mr. Wadsworth cut open a number of female colonies and preserved the eggs from the cœlentera.

Since Mr. Wadsworth's return a very large number of complete series of sections through the embryos have been cut, stained, and mounted, and I have carefully examined them, making notes and drawings of interesting points. As the work is not yet finished, and there are still many specimens to examine, it would be premature to do more than to point out some of the results of the investigation. These results are given only provisionally, and will be subjected to confirmation or the reverse before being finally published with the illustrations. 1. The ovum of Alcyonium is never fertilised before it leaves the body of the parent. 2. Soon after leaving the polyp the ovum enlarges, probably by the absorption of water, and the membranes covering it are broken and lost. 3. The nucleus which is at the edge of the ovum diminishes in bulk, and is then dissipated and lost to view. No karyokinetic figures accompany these changes in the nucleus. I may add here that these observations confirm the results I have obtained from material collected in the winters 1893–4, 1895–6, 1896–7.

4. Another nucleus, much smaller than the germinal vesicle, may be found in the ovum in what appear to be later stages. This is accompanied by archoplasm (?), and travels towards the centre of the ovum and then fragments.

5. Segmentation is very irregular in Alcyonium, as it is in Renilla, according to Wilson. Sometimes embryos with four, eight, or an irregular small number of well-defined blastomeres are to be found, but more frequently—perhaps normally—no segmentation occurs for some time, and then the embryo segments into twenty or more tightly-packed blastomeres, the outlines of which cannot be seen from the outside at all.

6. In all the well-preserved embryos which are segmented the nuclear structure is clear and definite, and in most of my series beautiful karyokinetic figures may be seen in one or more of the segments.

7. A complete series of the later stages of development up to the time of the formation of the mouth has been obtained. This series will be studied when the earlier stages have been more satisfactorily worked out.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor W. A. HERDMAN, Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor McINTOSH, Mr. W. E. HOYLE, *and* Mr. PERCY SLADEN (*Secretary*).

THE table in the Naples Zoological Station hired by the British Association has been occupied during the past year by Mr. James F. Gemmill, Mr. H. M. Vernon, and Mr. J. Parkinson.

Mr. Gemmill, who occupied the table from August 20 to November 12, was engaged in investigating certain points in the anatomy of the osseous fishes.

Mr. Vernon held the table from October until the middle of January, and continued his investigations on the conditions of animal life in marine aquaria, with a view to determine the relations existing between marine animal and vegetable life. Mr. Vernon also made careful experimental researches on the relations between the hybrid and parent forms of echinoid larvæ.

Mr. Parkinson occupied the table from October 25 to April 26, and devoted himself to the investigation of the variation of certain lamellibranchs.

Each of these gentlemen has furnished a report upon the work done, which will be found appended.

Your Committee has again to remark with gratitude on the kindness of Professor Dohrn in allowing the terms of occupancy in these cases to run concurrently, at least during part of each period. Without this courteous treatment on the part of Professor Dohrn, the Committee would have been unable to meet the wishes of the several workers.

An application for permission to use the table during the ensuing year has been received from Mr. H. Lyster Jameson, for the purpose of making investigations on the anatomy of the Gephyrea. He wishes to go to Naples at the beginning of October and to remain six months. This application is recommended by your Committee, and they trust that the General Committee will sanction the payment of the grant of 100*l.*, as in previous years, for the hire of the table in the Zoological Station at Naples.

The progress of the various publications undertaken by the station is summarised as follows :—

1. Of the 'Fauna und Flora des Golfes von Neapel' no monograph

has been published during the past year, but several are in course of preparation.

2. Of the 'Mittheilungen aus der zoologischen Station zu Neapel,' vol. xii., part 4, with 12 plates; and vol. xiii., part 1, with 11 plates, have been published.

3. Of the 'Zoologischer Jahresbericht,' the Bericht for 1896 has been published.

4. A new Italian edition of the 'Guide to the Aquarium' has been published.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers, will be found at the end of this report. They embrace lists (1) of the naturalists who have occupied tables since the last report, and (2) of the works published during 1897 by naturalists who have worked at the Zoological Station.

I.—*The Pseudobranch and Intestinal Canal of Teleosteans.*

By JAMES F. GEMMILL.

I occupied a table at the Naples Zoological Station between the end of August and the beginning of November, 1897. My work there had to do mainly with certain points in the anatomy of the osseous fishes; in particular, with the distribution, structure, and development of the pseudobranch, and with the intestinal canal. Over fifty species of teleosteans were examined.

A. *Pseudobranch.*

As far as the general anatomy and relations of this organ are concerned, I could only, in the case of the greater number of species examined, go over ground which was worked out long ago by Joh. Müller. Records were, however, made for a certain number of species not included in his list. But in every case, which was carefully examined, the great fact established by Joh. Müller that the pseudobranch is supplied by oxygenated blood was found to hold good. Comparative details as to the presence and degree of modification of the pseudobranch were specially noted whenever possible in allied species and genera. In this connection the flat fishes were found to form an interesting group. On the whole a good series of stages was obtained, illustrating on the one hand the gradual disappearance of the organ in question, and on the other its passage from a free projecting condition to one in which it is encapsuled and glandular.

The microscopical structure of the organ was investigated in a certain number of species. The results obtained agree in the main with what had been previously described, but there was also found in some cases (*e.g. Serranus gigas*), external to the layer of large polygonal cells which lies superficial to the capillaries in each lamella, another layer of flattened scale-like cells. These persist even when the pseudobranch becomes encapsuled and glandular, though in that case they do not form a continuous stratum, but are represented by scattered squamous cells lying between adjacent lamellæ.

A study of the development of the gland in *Hippocampus brevirostris* and *Syngnathus acus* by the method of serial sections of embryos was begun. The lophobranch group was chosen for investigation, because in the adults of this group the pseudobranch presents every appearance of being in uninterrupted series with the ordinary gills ; that is to say, it lies far back, being just in front of the first permanent gill cleft, and it shows the characteristic tufted structure of the lophobranch gill. I was unable at the time to complete my observations on its development, but they were advanced enough to convince me that the conclusion arrived at for other osseous fishes by Joh. Müller and Anton Dohrn held good also for the lophobranchs—namely, that the pseudobranch originates in front of the hyomandibular cleft and groove, and that therefore it is homologous so far with the spiracular pseudobranch found in many of the cartilaginous fishes.

B. *Intestinal Canal.*

The intestinal canal of osseous fishes is well known for its extreme variability in regard to length windings and mesenteric relations. I hoped by studying these points in the comparatively large number of species placed at my disposal to be able to define the characteristic tendencies in the way of morphology which might be expected to be shown by a series of examples ranging from the simpler to the more complex forms of intestinal tube.

As a result, I have come to these conclusions for all the fishes I examined :

1. That in any given case the anatomy of the intestinal tube can be regarded either as corresponding directly to, or as being easily derivable from, some one out of a small number of typical forms.

2. That the typical forms themselves constitute a natural series, of which the more complex members can readily be derived from the simpler.

Not the least interesting part of my observations had to do with the changes in the morphological scheme indicated above that are produced in the case of certain groups which vary in general form more or less considerably from the ordinary piscine type, *e.g.* in the pleuronectids, which are flattened laterally, or in *Lophius Piscatorius*, where the flattening is dorsoventral, &c. Here also must be included those fishes which have the vent carried forward to the front of the abdomen. In all these cases the modified course of the intestinal tube can still be referred to one or other of the typical forms indicated above, by taking in each instance the special factors at work into consideration.

In addition to investigation, one of the objects of my visit to Naples was to get some knowledge of the working of a marine zoological station. For furthering this, as well as for every assistance in work, I have to acknowledge the kindness and courtesy of the station staff. I consider it a very great privilege to have occupied a table at the Naples Zoological Station, and I hereby tender my sincere thanks to the Committee of the British Association for having afforded me that privilege.

II.—(1) *The Relations between Marine Animal and Vegetable Life in Aquaria ;* (2) *The Relations between the Hybrid and Parent Forms of Echinoid Larvæ. By* H. M. VERNON.

In the report which I furnished last year, I described the work on which I had been engaged during my occupancy of the British Association table at Naples between the months of April and June. I continued to work at the Zoological Station till the middle of the following January, but I only held the British Association table from October onwards, I being transferred to the Oxford table during July, August, and September. As it is scarcely possible to describe only those portions of the work I was engaged upon when occupying the British Association table, I will now furnish a brief report of the whole of the work I undertook during my stay at Naples.

In my last year's report I stated that I was investigating the conditions of animal life in marine aquaria. I continued to work on this subject for several months, and have embodied my results in a paper which will shortly be published in the 'Mittheilungen aus der zoologischen Station zu Neapel,' and which is entitled 'The Relations between Marine Animal and Vegetable Life.' An abstract of the paper has already been published.[1] It is on this account unnecessary to describe the research in any detail; but I should like to take this opportunity of drawing attention to the scope and practical bearing of the work, as it might thereby be brought to the notice of some persons who are interested in the subject, but who, judging from the title of the paper, might imagine it did not concern them. Thus the original object of the work was to determine how the nitrogenous matter excreted by marine animals into the water is removed, and what parts the various forms of vegetable life and other agencies play in the process. This subject is of interest from its practical bearing on questions relating to the efficient maintenance of marine aquaria, whilst from the theoretical standpoint it is of importance to our comprehension of the changes taking place under natural conditions in the open sea. The method of investigation was a triple one—viz., chemical, physiological, and bacteriological. The chemical procedure consisted in determining the free and 'albuminoid' or organic ammonia present in the water by the well-known method of Wanklyn, Chapman, and Smith. The physiological procedure consisted in allowing the fertilised ova of the sea-urchin (*Strongylocentrotus lividus*) to develop in the various specimens of water, and then, after eight days' growth, killing and measuring the larvæ in groups of fifty, in order to determine the changes produced in their size. The bacterial quality of the water was tested by counting the number of colonies obtained on gelatin plate culture.

The three chief vegetable agencies concerned in the purification of the water are—(1) the macroscopic algæ; (2) the diatoms and microscopic algæ; (3) the bacteria. It was concluded that under natural conditions in the open sea the bacteria form the most important of these purifying agencies. Thus, as considerably the larger portion of the water of the ocean extends to depths such that no trace of light can penetrate, it follows that no chlorophyll containing organism can exert an influence on it. As B. Fischer[2] has shown, however, bacteria are everywhere present. Now it was found that if the impure aquarium water was kept in darkness for about three weeks, it might become as pure, in respect of the ammonia it contained, as open sea water collected 10 kilomètres from the shore. Judged by the physiological standard, however, it was not nearly so pure. Thus larvæ grown in it were on an average only 7·5 per cent. larger than those grown in the impurified aquarium water, whilst those grown in the open sea-water were 16·0 per cent. larger. In marine aquaria it seems probable that bacteria play a considerable part in maintaining the purity of the water, even though the water may be stored for but very short periods

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[1] *Proc. Roy. Soc.* vol. lxiii. p. 155.

[2] 'Ergebnisse der Plankton Expedition der Humboldt-Stiftung,' *Die Bakterien des Meeres* (Bd. iv. M.g.)

in dark reservoirs, where the bacteria can most efficiently exert their influence. Thus, at Naples, it was found that the pipes conducting the water from the reservoirs to the rooms were coated internally with a layer of bacterial slime, and that in its passage along these pipes the water underwent considerable purification. For instance, water drawn off from one of the taps was found to contain from 26 to 82 per cent. less free ammonia and from 16 to 25 per cent. less organic ammonia than the water in the supplying reservoir. Also, larvæ grown in such water were increased about 7·8 per cent. in size.

Probably, in marine aquaria, a more powerful purifying influence than the bacterial is exerted by the diatoms and minute algæ. Thus sand collected from the bottom of one of the tanks was found to be impregnated with this vegetable growth, which clung to each grain and particle. On filtration of aquarium water through this sand, no less than 94 per cent. of the free ammonia, and 18 per cent. of the organic, were removed. Again, on filtering water in a continuous stream through a layer of sand which originally contained no vegetable matter, this matter was gradually deposited from the water, and the sand gradually developed a capacity for purification which became more and more marked with time. Such a vegetable filter is very sensitive to any variation in the flow of water. Thus, if the rate of flow were diminished from the maximum of one litre in three minutes to one litre in fifty minutes or more, there was no longer any purification, but the amount of free ammonia in the water was increased about threefold. This result is of some practical importance. It teaches us that the layer of slime which is deposited on the bottom and sides of the tanks of marine aquaria, and which consists largely of diatoms and algæ, is a most valuable purifying agent, provided it be in layers thin enough for an adequate amount of water to circulate to all parts of it. Once, however, the lower layers are insufficiently supplied, they begin to decompose, and become a source of contamination.

It was found that a sand filter, even when kept for weeks in darkness, continued to exert a purifying influence. In this case the influence must have been due to bacteria, and not to chlorophyll containing organisms. This bacterial filter acted most efficiently with a slower rate of filtration, and was not nearly so sensitive to a diminution or cessation in the flow of water. With regard to the purifying agency of the macroscopic algæ, experiments were made on the purifying effects of green weeds such as *Ulva*, and of red weeds such as *Gelideum*. Their action was not found so favourable as that of diatoms and minute algæ, and of bacteria, in consequence of the difficulty experienced in getting them to live healthily in the impure aquarium water.

To the other results obtained it is not possible to refer here at any length. Thus the action of sunlight on the water was investigated, it being found that though an immediate germicidal effect was brought about, the ultimate effect, on withdrawal of the adverse influence, was slight or absent. Again, the effects of increased aëration were investigated, but the influence exerted appeared to be but slight.

Numbers of experiments were made upon the fouling effects of various animals on the water. As a rule, larvæ grown in water fouled by most organisms were *increased* in size by, on an average, 4·1 per cent., whilst in water fouled by sea-urchins they were diminished in size by 6·9 per cent. Fish and crabs appeared to effect about ten times as much contamination of the water as molluscs and holothurians, whilst dead and putrefying sea-urchins effected about ten times as much contamination as did the various living animals examined.

In the full paper are given numerous determinations of the specific gravity of the aquarium water, and of the amounts of ammonia and nitrites present; also experiments on the effects of introducing various salts into the water. To these it is unnecessary to refer here.

During the last two or three months of my stay at Naples I was working on another subject, 'The Relations between the Hybrid and Parent Forms of Echinoid Larvæ,' but I had also been making occasional experiments on this subject whilst engaged on the research just described. I also worked out some of the material obtained on my return to England. An account of this work is in course of publication in the 'Phil. Trans. Roy. Soc.', an abstract having already appeared in the 'Proc. Roy. Soc.' vol. 63, p. 228. The object of the research was to determine systematically, during the nine months' period I was working at Naples, the exact relationship of structure and size existing between certain hybrid and parent echinoid larval forms. Eight different species of echinoids were worked with, but the large number of observations were confined to three of them. Upon the cross *Sphærechinus* ♀ *Strongylocentrotus* ♂ twenty-two experiments were made. The hybrids were most easily obtained in the summer months, few or none of the ova being cross-fertilised in the winter. It was found that the majority of the hybrids obtained in May, June, and July were of an almost pure *Sphærechinus* type, only a third or less of them being of an intermediate or *Strongylocentrotus* type. In November, on the other hand, only about a sixth were of the maternal and five-sixths of the paternal type. Finally, in December and January, all the hybrid larvæ were of the paternal type. As regards the reciprocal cross of *Strongylocentrotus* ♀ and *Sphærechinus* ♂ a fair number of ova were cross-fertilised in April, May, and June, but no plutei were obtained. In July and August, on the other hand, 29 per cent. of the ova developed to eight days' plutei. In November and December, with one exception, not only were no plutei obtained, but, as a rule, not a single ovum was cross-fertilised. These extraordinary variations in the capacity for cross-fertilisation seem to be due to variations in maturity which the sexual products undergo with change of season. Thus in the summer months most of the *Strongylocentrotus* individuals contain but very small quantities of ripe sexual products or none at all. Also it was found that the normal plutei obtained in July and August were 20 to 30 per cent. smaller than those obtained in April and May, and also in November and December. At intermediate times the larvæ were of intermediate size. We see, therefore, that the *Strongylocentrotus* ♀ *Sphærechinus* ♂ hybrid is only formed at the time when the *Strongylocentrotus* ova have reached their minimum of maturity; whilst in the case of the reciprocal hybrid it follows that as the maturity of the *Strongylocentrotus* sperm increases it is able to transform first a portion and then the whole of the hybrid larvæ from the *Sphærechinus* to its own type. In other words, the characteristics of the hybrid offspring depend directly on the relative degrees of maturity of the sexual products.

On crossing *Echinus* ♀ with *Strongylocentrotus* ♂ it was found that even more of the cross-fertilised ova developed to plutei than of the directly fertilised ones, and also that these plutei were, on an average, 8 per cent. *larger* than the pure parental larval forms. In the reciprocal cross, however, only about 1 per cent. of the ova reached the pluteus stage, and these plutei were 13·2 per cent. smaller than the pure maternal larvæ.

Crosses were also effected between the forms mentioned and *Arbacia pustulosa, Echinocardium cordatum, Echinocardium mediterraneum, Dorocidaris papillata,* and *Echinus acutus.* Also the various colour varieties of *Sphærechinus* were crossed, a distinct diminution of fertility being found to exist between dissimilar varieties. With the colour varieties of *Strongylocentrotus,* however, this was not the case.

In conclusion, I wish to offer my thanks to the Committee of the British Association for the privilege of being allowed to hold the table, as well as to the authorities at the Zoological Station at Naples for their invariable kindness and for the facilities they were able to afford me in my work. How great these were may be gathered from the fact that I was able to carry on the chemical, physiological, and bacteriological portions of my work simultaneously. As regards echinoid material also I was afforded an absolutely unlimited amount, and as regards the artificial fertilisations I was enabled, when necessary, to keep fifty or more large jars of plutei developing at one and the same time.

III.—*On the Variation of Cardium, Donax, and Tellina.*

By J. Parkinson.

It was my intention in visiting the Zoological Station at Naples during the winter of 1897–98—*i.e.* from November to April inclusive—to attempt an investigation on the reproduction of certain Ascidians. However, a short visit to Plymouth, with some subsequent study, early in last year raised sundry objections, and on reaching Naples in the beginning of November I gave up the subject which has just been mentioned, taking in its place the one which appears at the head of this report. I began upon the genus Arca, comparing the variation in certain proportions exhibited by the commoner species of that genus one with another, but found after several attempts that the confined space in which the animals grew, due to the nature of their attachment, raised great difficulties in the way of forming any true estimate of their natural variation. I then proceeded to the genus Cardium, and subsequently to the genera Donax and Tellina, comparing the variation in the chosen proportions of the several species one with another, as in the case of Arca. Here I was more successful; but in finding a reasonably certain, and, at the same time, fairly quick method of measuring, as well as in overcoming the difficulty of obtaining definite points from which to measure, much time was spent. The work is now undergoing entire revision in the laboratory at University College, London. Material for subsequent investigation was also obtained from such experiments as the resistance of Pecten to diluted sea-water, but this has not yet been studied. Although a considerable number of measurements have been made, I have not at present reached that degree of certainty which makes it desirable that results should be given in length. It gives me great pleasure to testify to the extreme kindness shown by all the members of the station at Naples, especially to Signor Lo Bianco for the efforts he made to satisfy my rather large demands for material. To Professor Weldon my warmest thanks are gratefully given for the very kind help he has afforded me not only by letter, but since I returned to England. In doing such work as that indicated above this has been simply invaluable.

IV.—*A List of Naturalists who have worked at the Zoological Station from the end of June* 1897 *to the end of June* 1898.

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
970	Dr. D. Carazzi	Italy	July 1, 1897	Aug. 1, 1897
971	Prof. F. S. Monticelli	„	„ 19, „	Dec. 31, „
972	Dr. F. Bottazzi	„	„ 20, „	Sept. 29, „
973	Dr. G. Mazzarelli	„	„ 26, „	„ 30, „
974	Dr. A. Romano	„	Aug. 1, „	—
975	Dr. V. Diamare	„	„ 1, „	—
976	Dr. A. Russo	„	„ 1, „	Oct. 4, „
977	Dr. F. Mazza	„	„ 4, „	Sept. 14, „
978	Dr. R. Hesse	Würtemberg	„ 18, „	Oct. 13, „
979	Mr. J. F. Gemmill	British Association	„ 20, „	Nov. 12, „
980	Prof. F. Ezokor	Austria	Sept. 5, „	Oct. 10, „
981	Prof. E. Drechsel	Switzerland	„ 11, „	Sept. 22, „
982	Mr. K. R. Menon	Cambridge	„ 20, „	May 14, 1898
983	Dr. A. G. H. van Genderen-Stort	Holland	„ 20, „	Dec. 12, 1897
984	Prof. G. B. Grassi	Italy	„ 20, „	Nov. 20, „
985	Prof. W. Krause	Prussia	„ 23, „	Oct. 7, „
986	Stud. O. Fragnito	Italy	„ 24, „	—
987	Dr. F. Doflein	Bavaria	„ 25, „	Nov. 7, „
988	Dr. H. Driesch	Prussia	Oct. 2, „	May 5, 1898
989	Dr. C. Herbst	„	„ 3, „	„ 30, „
990	Mr. K. A. Buddicom	Oxford	„ 10, „	—
991	Dr. E. Albrecht	Bavaria	„ 16, „	Mar. 1, „
992	Mr. J. Parkinson	British Association	„ 25, „	Apr. 26, „
993	Dr. S. Metalnikoff	Russia	„ 28, „	June 1, 1898
994	Dr. B. M. Davis	Smithsonian Instit.	„ 29, „	Dec. 3, 1897
995	Dr. T. Beer	Austria	„ 30, „	Apr. 14, 1898
996	Dr. E. O. Hovey	Columbia Table	Nov. 3, „	Dec. 4, 1897
997	Dr. G. Duncker	Hamburg	„ 6, „	Apr. 15, 1898
998	Baron J. Uexküll	Prussia	„ 14, „	—
999	Dr. T. Adensamer	Austria	„ 20, „	Feb. 22, „
1,000	Dr. W. Stempell	Prussia	Dec. 14, „	Apr. 16, „
1,001	Prof. J. Nusbaum	Austria	„ 17, „	Jan. 7, „
1,002	Stud. W. Schreiber	„	„ 17, „	„ 7, „
1,003	Mr. E. Goodrich	Oxford	„ 23, „	„ 14, „
1,004	Mr. M. Hill	„	„ 24, „	„ 14, „
1,005	Dr. G. Tagliani	Italy	Jan. 1, 1898	—
1,006	Dr. G. Jatta	„	„ 1, „	—
1,007	Prof. A. Della Valle	„	„ 1, „	—
1,008	Dr. Count C. Attems	Austria	„ 17, „	May 24, „
1,009	Dr. F. Studnicka	„	„ 25, „	Apr. 5, „
1,010	Prof. K. von Bardeleben	Saxony	Feb. 4, „	„ 1, „
1,011	Prof. R. Bergh	Zoolog. Station	„ 8, „	May 4, „
1,012	Dr. H. Zwiesele	Würtemberg	„ 15, „	Mar. 24, „
1,013	Dr. A. Fischel	Austria	„ 17, „	Apr. 12, „
1,014	Prof. K. Mitsukuri	Zoolog. Station	„ 26, „	„ 18, „
1,015	Prof. R. Burckhardt	Switzerland	Mar. 4, „	May 1, „
1,016	Dr. E. Sauerbeck	„	„ 4, „	„ 1, „
1,017	Dr. G. Wetzel	Prussia	„ 4, „	Apr. 22, „
1,018	Prof. L. Jost	Strasburg	„ 5, „	„ 18, „
1,019	Prof. F. Oltmanns	Baden	„ 7, „	„ 22, „
1,020	Dr. R. Hesse	Würtemberg	„ 9, „	„ 16, „
1,021	Stud. G. Bugge	Hesse	„ 9, „	„ 19, „
1,022	Prof. F. Schütt	Prussia	„ 10, „	„ 21, „

IV.—A List of Naturalists—*continued.*

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
1,023	Prof. H. Ludwig .	Prussia . . .	Mar. 10, 1898	Apr. 14, 1898
1,024	Miss H. O'Neill .	Zoolog. Station .	„ 11, „	„ 22, „
1,025	Prof. H. W. Conn .	Smithsonian Instit. .	„ 11, „	„ 24, „
1,026	Prof. Dr. Mottier .	„ .	„ 12, „	„ 18, „
1,027	Prof. H. Hoyer . .	Austria . . .	„ 16, „	June 6, „
1,028	Dr. J. Sobotta . .	Prussia . . .	„ 18, „	May 1, „
1,029	Dr. H. Lebrun . .	Belgium . . .	„ 18, „	—
1,030	Mr. W. Swingle .	Smithsonian Instit. .	„ 22, „	Apr. 28, „
1,031	Dr. A. Russo . .	Italy . . .	Apr. 6, „	May 4, „
1,032	Prof. Miss M. Willcox	American Women Table	„ 9, „	„ 20, „
1,033	Prof. K. Lampert .	Würtemberg . .	„ 10, „	„ 7, „
1,034	Mag. N. Koltzoff .	Russia . . .	„ 11, „	—
1,035	Miss H. von Siemens.	Zoolog. Station .	„ 12, „	„ 29, „
1,036	Prof. A. Nicolas .	„ „ .	„ 13, „	„ 15, „
1,037	Dr. C. Alessi . .	Italy . .	„ 23, „	June 22, „
1,038	Mr. F. Schaible .	Würtemberg . .	„ 25, „	„ 15, „
1,039	Dr. D. Carazzi . .	Italy . . .	„ 26, „	—
1,040	Dr. G. Mazzarelli .	„ . . .	„ 27, „	—
1,041	Cand. H. F. Nierstrase	Holland . . .	May 10, „	—
1,042	Prof. J. Ogneff .	Russia . . .	June 25, „	—
1,043	Dr. M. Gardner .	„ . . .	„ 25, „	—

V.—*A List of Papers which were published in the Year* 1897 *by the Naturalists who have occupied Tables in the Zoological Station.*

H. Boruttau . . .	Der Elektrotonus und die phasischen Aktionsströme an marklosen Cephalopodennerven. 'Archiv. f. d. ges. Physiologie,' 66 Bd., 1897.
N. Iwanzoff . . .	Muskelelemente der Holothurien und ihr Verhalten zum Methylenblau. 'Arch. Mikr. Anat.,' Bd. 49, 1897.
E. Goodrich . . .	On the Nephridia of Polychæta. Part I., On Hesione, Tyrrhena, and Nephthys. 'Quart. Journ. Micr. Science,' vol. 40, 1897.
„ . . .	Notes on the Anatomy of Sternaspis. *Ibid.*
P. Celesia . . .	Sul differenziamento delle proprietà inibitorie e delle funzioni coordinatrici nella catena gangliare dei crostacei decapodi. 'Atti Soc. Ligustica Sc. Nat. e Geogr.,' vol. 8, 1897.
G. Brandes . . .	Zur Begattung der Dekapoden. 'Biol. Centralblatt,' Bd. 17, 1897.
„ . . .	Die Spermatozoen der Dekapoden. 'Sitz. Ber. k. Preuss. Akad. Wiss.,' Bd. 16, 1897.
W. T. Swingle . .	Zur Kenntniss der Kern- und Zellsheitung bei den Sphacelariaceen. 'Jahrb. f. wiss. Botanik.,' Bd. 30, 1897.
G. Schneider . . .	Ueber die Niere und die Abdominalporen von Squatina angelus. 'Anat. Anz.,' Bd. 13, 1897.
F. M. MacFarland . .	Celluläre Studien an Mollusken-Eiern. 'Zool. Jahrbücher.' Abth. f. Anat. u. Ontog., Bd. 10, 1897.
A. Russo . . .	Sul coridetto canale problematico delle Oloturie. 'Boll. Soc. Nat. Napoli,' vol. 11, 1897.
J. Sobotta . . .	Beobachtungen über den Gastrulationsvorgang beim Amphioxus. 'Verh.-Phys.-Med. Ges. Würzburg,' Bd. 31, 1897.
„ . . .	Die Reifung und Befruchtung des Eies von Amphioxus lanceolatus. 'Archiv f. micr. Anatomie,' Bd. 50, 1897.

V. Diamare	Anatomie der Genitalien des Genus Amabilia. ‘Centralbl. Bakteriologie,’ Bd. 21, 1897.
„	Die Genera Amabilia u. Diploposthe, Nachtrag. *Ibid.* Bd. 22, 1897.
S. Apáthy	Das leitende Element des Nervensystems u. seine topographischen Beziehungen zu den Zellen. 1. Mitth. ‘Mitth. Zoolog. Station, Neapel,’ Bd. 12, 1897.
G. v. Koch	Entwickelung von Caryophyllia cyathus. *Ibid.*
Th. Beer	Accomodation des Cephalopodenauges. ‘Archiv. f. d. ges. Physiologie, Pflüger,’ Bd. 67, 1897.
J. Ogneff	Ueber die Entwickelung des electrischen Organes, bei Torpedo. ‘Arch. Anat. Phys.,’ Phys. Abth., 1897.
A. Romano	Sopra le fibre commessurali del Proencefalo dei Selacei. ‘Monitore Zoolog. Ital.,’ Anno 8, 1897.
O. Van der Stricht	Les ovocentres et le spermatocentre de l’ovule de Thysanozoon Brocchi. ‘Verhandl. Anat. Ges.,’ 1897.
H. Driesch	Ueber den Werth des biol. Experiments. ‘Arch. Entw.-Mechan.,’ Bd. 5, 1897.
„	Von der regulären Wachsthums- u. Differenzirungsfahigkeit der Tubularia. *Ibid.*
F. Noll	Pfropf- u. Verwachsungsversuche mit Siphoneen. ‘Sitz. Ber. Nat. Ver. Bonn.
A. Borgert	Beiträge zur Kenntniss der in Stilolonche zanclea und Acanthometridenarten vorkommenden Parasiten. ‘Zeitschr. Wiss. Zoologie,’ Bd. 63, 1897.
F. K. Studnicka	Ueber das Gewebe der Chorda dorsalis und den sog. Chordaknorpel. ‘Sitz. Ber. Böhm. Ges. Wiss.,’ 1897.
K. Kostanecki	Ueber die Herknuft der Centrosomen der ersten Furchungsspindel bei Myzostoma glabrum. ‘Anzeiger K. Akad. Wiss. Krakau,’ 1897.
C. Herbst	Ueber die zur Entwickelung von Seeigellarven nothwendigen anorganischen Stoffe, ihre Rolle und ihre Vertretbarkeit. ‘Arch. f. Entw. Mechanik,’ Bd. 5, 1897.
G. Mazzarelli	Contributo alla conoscenza delle Tylodinidæ, nuova famiglia del gruppo dei Molluschi tectibranchi. ‘Zool. Jahrbücher,’ Abth. f. Systematik, Bd. 10, 1897.
V. Faussek	Untersuchungen über die Entwickelungsgeschichte der Cephalopoden. ‘Travaux Soc. Imp. des Naturalistes, St. Petersbourg,’ vol. 28, 1897.
„	Biologische Beobachtungen über Lamellibranchiaten. *Ibid.*
J. H. Hyde	Beobachtungen über die Secretion der sogenannten Speicheldrüsen von Octopus macropus. ‘Zeitschr. f. Biologie,’ Bd. 35, 1897.
G. Tagliani	Considerazioni morfologiche intorno alle cellule nervose colossali e alle cellule nervose giganti del medollo spinale di alcuni teleostei. ‘Monitore Zool. Ital.,’ Anno 8, 1897.
R. Krause	Ueber Bau und Function der hinteren Speicheldrüsen der Octopoden. ‘Sitz. Ber. K. Preuss. Akad. Wiss.,’ Bd. 51, 1897.
A. Fischel	Experimentelle Untersuchungen am Ctenophorenei. I, Von der Entwickelung isolirter Theile. ‘Archiv. Entw.-Mechanik,’ Bd. 6, 1897.
W. Krause	Die Farbenempfindung des Amphioxus. ‘Zool. Anz.,’ Bd. 20, 1897.
J. v. Uexküll	Der Schatten als Reiz für Centrostephanus longispinus. ‘Zeitschr. f. Biologie,’ Bd. 37, 1897.
„	Ueber Reflexe bei den Seeigeln. *Ibid.*
A. Bethe	Das Nervensystem von Carcinus mænas. Ein anatomisch-physiologischer Versuch. I Theil, 1. Mitthlg. ‘Archiv. Micr. Anatomie,’ Bd. 50, 1897.
	Idem, 2 Mitthlg.

A. Bethe	Vergleichende Untersuchungen über die Function des Centralnervensystems der Arthropoden. 'Archiv. f. d. ges. Physiologie,' Bd. 68, 1897.
F. S. Monticelli . .	Dictiomyxa Trinchesii g. sp. n. di Rizopode marine. 'Boll. Soc. Nat., Napoli,' vol. 11, 1897.
C. Child	A Preliminary Account of the Cleavage of Arenicola cristata, with Remarks on the Mosaic Theory. 'Zool. Bulletin Univ. Chicago,' vol. 1, 1897.

Photographic Records of Pedigree Stock.

By FRANCIS GALTON, *D.C.L. (Oxf.), Hon. Sc.D.(Camb.), F.R.S.*

[PLATE IV].

IT is my purpose shortly to communicate with the Councils of some of the Societies who publish stud or herd books, urging the systematic collection of photographs of pedigree stock and of more information about them than is now procurable. Believing that if my proposals were carried into effect, they would greatly facilitate the study of heredity, I desire, before approaching the Societies, to submit my intended proposals to the criticism of a scientific body, and none seems more appropriate for the purpose than the Zoological Section of the British Association.

The following remarks are based on the Ancestral Law, which will be explained. Its purport is to *measure* the importance to the breeder of taking into account the various members of the ancestry of the animals he proposes to mate together, so much of the heritage coming *on the average* from each of them. Then the methods of utilising this bulky knowledge will be discussed, that of composite portraiture being one means of dealing with numerous photographs; another way is by obtaining measures, which can be arithmetically combined, from the photographs themselves, provided they have been taken in accordance with certain simple instructions. Next, the plan will be explained by which the Societies referred to above might initiate and maintain a systematic collection of photographs and other information useful to breeders, which should become self-supporting. Lastly, an allusion will be made to the huge waste of opportunities of advancing the art of breeding that goes on unchecked.

The Ancestral Law.—I have lately shown how the general knowledge that offspring can inherit peculiarities from the various members of their ancestry as well as from their parents may be superseded by a definite law whose nature was first suggested to me by theoretical considerations. Being subsequently in a position to verify its accordance with a large number of pertinent facts, I submitted the results to the Royal Society in a communication entitled 'On the Average Contribution of each Several Ancestor to the Total Heritage of the Offspring.'[1] My theory was thoroughly examined from fresh points of view by Professor Karl Pearson, F.R.S., in one of his remarkable 'Contributions to the Mathematical Theory of Evolution,'[2] in which he showed that the theory accorded with other observations, and accounted for other conclusions that had already been reached. Assuming, then, that the Ancestral Law may be accepted

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[1] *Proc. Roy. Soc.*, 1897.

[2] *Ibid.*, 1898.

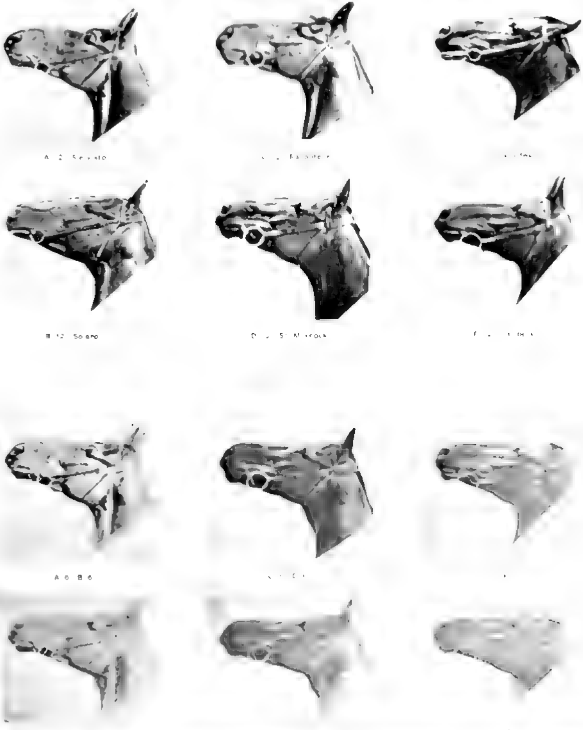
as at least approximately true, it will be found most serviceable in showing the relative importance and range of the data which breeders must take into account, if they pursue their art with thoroughness. The law is that, *on the average,* the two parents contribute between them one-half of the total heritage of the offspring, that the four grandparents contribute between them one-quarter, the eight great-grandparents one-eighth, and so on. Consequently, since $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\&c.=1$, the whole of the heritage is accounted for. The same law may be stated in another form, namely, that each parent contributes *on the average* one-quarter, each grandparent one-sixteenth, each great-grandparent one sixty-fourth, and so on. It is a property of the first series of fractions that each term is equal to the sum of all those that follow ($\frac{1}{2}$ being equal to $\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\&c.$; $\frac{1}{4}$ to $\frac{1}{8}+\frac{1}{16}+\&c.$), therefore it results that if genealogical knowledge should cease with the grandparents, inasmuch as they contributed one-quarter, another quarter of the heritage will remain indetermined; if it ceases with the great-grandparents one-eighth will remain indetermined; if with the next ascending grade, one-sixteenth, &c.

[It must be understood that the law is intended to apply only to what may be called *plain* heredity, that is to cases where qualities are capable of blending freely, or, if they refuse to blend, where they present themselves as alternative possibilities. The necessary modifications have yet to be investigated when it has to be applied to hybrid heredity, and to those partial forms of hybridism which occur in cross-breeding, especially in plants, where two parental qualities seem to produce a third and different quality in the offspring. Again, it takes no notice of prepotency, because it considers prepotency as likely to occur with equal frequency in each and all of the ancestral places, but when the prepotencies of particular ancestors are known or suspected it is easy to take them into account. Similarly the law takes no cognisance of the prepotency of one sex over the other, which must be allowed for in those particular races and qualities where it is known to exist. Lastly, as it relates to averages, its predictions will be truer for the mean of many offspring than for any one of them in particular. However, as we know that fraternal variation admits of being defined with mathematical precision for any measurable quality in any race, the diminution in trustworthiness when a prediction relating to a fraternity is applied to a single member of it, is easily calculated.]

The ancestral law specifies the number, the grades, and the relative importance of the ancestors whom breeders must take into account, in order to predict with any given degree of certainty the *most probable* character of the future produce. It clearly shows the necessity of a much more comprehensive system of records than now exists. A breeder ought to be in a position to compare the records of at least the four parents of the animals he proposes to mate together, in respect to the qualities in which he is interested. More especially he ought to have access to photographs which indicate form and general attitude far more vividly than verbal descriptions. But the information in stud and herd books is too meagre for the requirements of the breeder, while the photographs published in newspapers and elsewhere are inadequate for making complete genealogical collections.

Utilisation of the Records.—My principal suggestion is that a system of collecting photographs should be established, which would be serviceable

PORTRAITS of RACE HORSES and COMPOSITES of them



to breeders. They should be serviceable to them not only as portraits, but also as affording means of obtaining measurements of the animal. It will be shown that the system might be easily initiated, and be afterwards self-supporting, but for the moment it will be convenient to take these important conditions on trust, and to begin by considering what could be done if we had the photographs. I will suppose, then, that the system has been in successful operation for many years and that it has become possible to obtain photographs of the parents, grandparents, and other ancestors of each of a large number of pure-bred horses and cattle taken under specified conditions. We have to explain how such photographs might be employed in improving the art of breeding.

An habitual study of the form of each pure-bred animal in connection with the portraits of all its nearer ancestors would test current opinions and decide between conflicting ones, and it could not fail to suggest new ideas. Likenesses would be traced to prepotent ancestors and the amount of their several prepotencies would be defined; forms and features that supplement one another, or, as it is termed, 'nick in,' and others that clash or combine awkwardly, would be observed and recorded: conclusions which are based on incomplete and inaccurate memories of the appearance of the several members of the ancestry would be superseded by others derived from a study of their actual photographs. The value of the ancestral law would be adequately tested, and it would be possible to amend it where required. Thus the effects of organic stability, to which I have often called attention, have yet to be dealt with if they are not indirectly included in the law as it stands. Lastly, it is not unreasonable to suppose that every important stallion or bull would have a pamphlet all to himself, with photographs of his ancestors, and with appropriate particulars about each of them. Such pamphlets would become recognised as a just form of advertisement.

Composite Photography.—It may be said that, even if all the ancestral photographs were spread in full view on a table, no human brain could combine into a single mental image the peculiarities in feature even of the two parents, and of the four grandparents, in the proportion laid down by the ancestral law. There is, however, a method by which a substitute for a mental picture may be obtained, which may possibly prove serviceable in practice. It is by making composites of the photographs, allotting to each portrait its appropriate time of exposure.[1] I submit a few composites which I have made of the heads of racehorses: the component portraits are from the earlier numbers of the 'Racing Illustrated.' I enlarged them to an uniform scale, reckoning from the middle of the eyeball to the fold within the nostril, cut them out to get rid of the confusion introduced by a variety of background, and then combined them in various proportions. Especially I took six, those of (A) Sir Visto, (B) Solaro, (C) Raconteur, (D) St. Marnock, (E) Speedwell, and (F) Salebeia, which will henceforth be distinguished by those letters. With the plate, stop, and the two small electric lamps that I used for illumination, it required an exposure of 240 seconds, say of 12 units of time, each consisting of 20 seconds, to give a good copy of any one of the portraits, so I proceeded as follows:—First, I made a composite of A and B, allowing 6 units of exposure to each

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[1] Composite Portraits, *Nature*, 1878; Composite Portraiture, *Journ. Phot. Soc.*, 1881.

of them, or 12 units in all; then I made another composite of A, B, and the four others, allowing 4 units to A, 4 units to B, and 1 unit to each of the four others, forming a total as before of 12 units. So while the composite which I will call A 6, B 6, illustrates the combined features of the two parents, that of A 4, B 4, C 1, D 1, E 1, F 1 illustrates those of two parents and four grandparents in the proportions laid down by the ancestral law. I proceeded similarly with C, D and with C, D and the other four, and again with E, F and with E, F and the other four; I submit these six composites. Of course the process could be extended indefinitely, working backwards to include as many previous generations of ancestors as desired, and it might be equally well applied to portraits of other animals than horses, including men and women, whose features combine unexpectedly well in composites, though one sex be bearded and the other not. A composite may be made of any separate part of an animal, but hardly of the whole animal at once, because each separate joint is liable to be flexed differently in the different portraits. The ears of the horses in the illustration indicate what would then occur. This is not the place to enter further into the details of composite making, which I have now reduced to a very simple process whose accuracy is evidenced by the identity of the composites that have been re-made at different times from the same components. The specimens I submit would have been better if they had been made from the original photographs and not from photo-process copies of them, still they will serve to gauge the amount of information which composites are likely to give to the breeder. They should be carefully scrutinised and compared, when more differences and points of interest will be found than are apparent at a first glance.

Measurement of Photographs.—A photograph considered merely as a portrait tells about as much of an animal as can be gathered from a single view of it; it defines the contour, the slope of the shoulders, the set of the head, the forms and the positions of the limbs, but this is by no means all that is obtainable from a photograph. It may be so taken that measurements made upon the photograph, after certain corrections have been applied to them, will be nearly as good as those made on the animal itself. Now, measurements are of the highest importance to the theoretical study of heredity, for science is based on numerical data, and the science of heredity is no exception to the general rule. Its progress depends primarily upon the power of procuring large collections of measurements of the same parts, which admit of being combined in any proportions by simple arithmetic. It matters little what limb, or bodily part, or faculty is the subject of measurement, because laws which are true for one particular quality, and for one particular race of animals or plants, will presumably apply with small modifications to any other quality and race. Therefore it would be no unworthy occupation for a scientific man to devote years of labour to carefully measuring each of many parts in the photographs of offspring and their ancestry, and to discuss the results by the elaborate methods of the higher statistics.

The photographs of which I speak are assumed to have been taken under the following conditions. They would represent side views of the animals and therefore be comparable on equal terms so far as position is concerned. The animals would have been photographed at a distance of *not less* than thirty feet from the camera, in order to avoid sensible distortion of the portrait. They should be taken while standing on hard ground, that the feet may be clearly shown, and no mistake arise about their heights. The height of the camera above the ground and its distance from the animal should be roughly measured and noted. Lastly, two direct measurements of the height of the animal should be made, one at its withers, the other at its croup. The photograph now becomes more than a mere picture, because the recorded data, together with others afforded by the photograph itself, supply corrections that will cause the measurements made upon it to correspond with more or less accuracy to those made on the animal itself. Of course, their correspondence would not be so exact as it would be in photographs taken in a 'hippometric' laboratory provided with marked lines on the ground and walls, but such a laboratory is impracticable on many grounds. Thoroughbred horses are so easily frightened in unfamiliar places and at unfamiliar objects that the best plan is to photograph them leisurely among their accustomed surroundings. It is difficult and dangerous to apply tapes and calipers, which tickle and irritate, for thoroughbred horses are exceedingly sensitive, timid, fidgety, and often vicious, while they are supple and sudden in their movements of offence. Measurements of the two vertical heights, made in the usual way, are comparatively easy to manage.

I find, moreover, that vertical measurements of all kinds may be made quickly and accurately without touching the objects at all, by means of a simple instrument which I roughly put together for trial. [I submit its working part.] Its principle is that of a collimator, with additions and modifications. It seems very suitable for use at agricultural and other shows where many animals are collected.

Though many useful measurements can be made on a plain photograph, it would be a decided gain to select two, three or more important osseous protuberances, such as can be easily felt, and to mark their positions by sticking on the animal small wafers of sufficiently adhesive paper—say, one quarter of an inch in diameter. The corresponding marks on the photographs will be too small to attract notice, but they are easily found when looked for, and afford excellent points from which to measure. I may add that measurements I have made, and had made, both on horses and on their photographs, show that the relative dimensions of horses differ considerably. If some five different measurements were made on an adult racehorse, it would be as easy to identify him by a 'Bertillon process' as it is to identify prisoners.

It will be observed that the measured height of the animals at the wither and croup, supply a scale for vertical measures on the photograph at those points. If the line to which vertical measures are drawn on the photograph be the one that touches the edge of the feet nearest to the camera, a slight and simple correction has to be made. There is difficulty in respect to the relation between the vertical and the horizontal scales, but less so than might be anticipated, for the tilt of the camera is found closely enough by a rough knowledge of the height of the camera and its distance from the animal, combined with data supplied by the photograph itself. Again, the length between the rounded ends of the body, and the diameters of the limbs, are not sensibly affected by the animal standing very slightly askew. The necessary corrections admit of being easily found from appropriate tables. It is curious in how many different ways the required corrections may be determined when the range of available measures is slightly increased. I have already discussed the question for a different and more complicated series of data in 'Photographic Measurements of Horses and other Animals' (*Nature*, Jan. 6, 1898), which will show the general character of the problem, but I cannot enter into particulars now. The primary question is, will photographers and grooms take the proposed measurements with sufficient correctness, and are any additions to them feasible? To settle this question, many experiments should be concentrated by more than one photographer upon the same quiet and well-measured animals. These ought to determine the trustworthiness of the results according to the data in use, and would show the minimum of effort that is necessary to afford the required degree of accuracy. I should be content if the average error in the calculated height and length of the horse did not exceed one inch, or say one-and-a-half per cent.

Systematic Collection of Photographs.—It remains to consider what has hitherto been taken for granted—the best method of starting a systematic collection of photographs of pedigree stock. My proposal is to suggest to the principal Societies which publish stud or herd books, that they should proceed as follows:

(1) To arrange with a photographer to store such negatives as the Society may hand over to his charge; he undertaking to supply prints from them to the public at a moderate cost and under reasonable regulations.

(2) To invite owners of pure-bred stock to send to the Society with which they are in connection, a negative photographic plate of each of the animals which they use for breeding, and which are therefore adult, on the understanding that if the negative be accepted by the Society it will be handed over to the photographer.

(3) Only those negatives will be considered suitable for acceptance (*a*) which are of good quality; (*b*) which do not transgress specified limits of size; (*c*) which scrutiny shows to be strictly side views; (*d*) which have been taken at a distance from the animal of not less than 30 feet; and (*e*) which show the animal standing on hard ground.

(4) The following information is to be stamped or written on the negative in such a way as to be clearly legible in the prints: (1) the name and sex of the animal, (2) year of its birth, (3) year and month of taking the photograph, (4) heights at its withers and croup, (5) height of camera and its distance from the animal.

(5) The Society shall order an asterisk to be affixed to the name of each animal entered in its stud or herd book, when the photographic negatives of its sire and dam have been accepted.

It seems to me that a system such as this would be efficient, self-supporting and acceptable to all parties. Breeders would be pleased that photographs of their animals should be publicly recognised as serviceable for the advancement of their art. Owners of valuable animals are almost sure to order photographs of them on their own account, so the gift of the negatives to the Society would deprive them of nothing. The asterisks applied to the names of the offspring would be a valued distinction, and would help to introduce the system. Later on, when they had become common, the absence of an asterisk would excite suspicion and require explanation. Lastly, the printing of the photographs would be self-supporting. I have already expressed a belief that the custom would arise of printing a separate pamphlet for every important stallion or bull, containing its photograph and those of its nearer ancestors, together with other appropriate information. Larger publications of a more costly kind would doubtless be issued under the auspices of each Society, to correspond with an awakened demand for fuller information on the antecedents of pedigree stock.

Printed Records.—As regards useful additions to the printed matter in stud and herd books, I would now merely allude to the need for them, and to the propriety of carefully reconsidering how much of real utility could be asked for from breeders that they would supply willingly and truthfully. The measurements of adult animals, of which I spoke, would be appropriate entries. An accumulation even of these during two or three generations would be exceedingly valuable, considering how many coherent results in the science of heredity have been derived from observations of human stature, though limited to comparatively small numbers of parents and their offspring.

Conclusion.—The amount of money annually spent in rearing pedigree stock is enormous; so is the care and thought bestowed upon it, and so also is its national importance. The non-preservation of adequate records of pedigree stock is a cruel waste of opportunity, and has been most prejudicial to the acquirement of a sound knowledge of the art of breeding. If the scheme I have sketched be found feasible, it will cause much to be noted that has hitherto been overlooked, and much that is commonly observed to be placed permanently on record, instead of being ill remembered and soon wholly forgotten.

The Climatology of Africa.—Seventh Report of a Committee consisting of Mr. E. G. RAVENSTEIN (*Chairman*), Sir JOHN KIRK, Mr. G. J. SYMONS, Dr. H. R. MILL, *and* Mr. H. N. DICKSON (*Secretary*). (*Drawn up by the Chairman.*)

METEOROLOGICAL returns have reached your Committee, in the course of last year, from twenty-six stations in Tropical Africa.

Niger Territories.—No returns have been received from Wari since the hostile operations against Benin, and there is reason to believe that the instruments at that station have been destroyed. Mr. E. G. Fenton has forwarded three months' observations from Old Calabar. These will be published as soon as a full year's record is to hand. The promised abstracts of observations from several stations in the territories of the Royal Niger Company have not hitherto been received.

Lambarene (Ogowai).—The set of instruments lent to the late M. Bonzon of the 'Missions Evangéliques' has been returned to Paris. The Rev. M. Coillard, well known for his excellent work in the Barotse country, and a trustworthy observer, having expressed a desire to purchase these instruments for 6*l.*, the Committee have gladly accepted this offer, as a station in that part of Africa is much wanted. The set has been repaired and completed, and the thermometers have been re-verified at Kew.

British Central Africa.—The organisation of the Meteorological service in British Central Africa has been intrusted to Mr. J. McClounie, the head of the scientific department of that Protectorate. From the great interest taken in the work by Mr. Alfred Sharpe, H.M.'s Commissioner, and Captain W. H. Manning, his deputy, we may fairly expect that the climatological conditions of this Protectorate will soon become thoroughly well known. The grant made by the Foreign Office has enabled Mr. McClounie to equip two Second Order stations (Zomba and Fort Johnston) and ten climatological stations. Mr. Moir, meanwhile, has resumed his work at Lauderdale, and Mr. McClounie is endeavouring to enlist the co-operation of planters and other residents. Returns for from three to four months have already been received from ten stations, including one from Kambola, on the Tanganyika Plateau, from Dr. J. G. Mackay. The instruments lent to the late Mr. Buchanan have been recovered, with the exception of the mercurial barometer, but they were found by Mr. McClounie to be in a sad state of disrepair.

British East Africa.—Returns from nine Government stations have been received up to the end of 1897. These returns, owing to the occasional illness of the officials charged with the observations, and temporary absences, are not as complete as could be desired, but in default of something better they have added considerably to our knowledge of the climatological conditions of this Protectorate, especially as regards the rainfall. We have succeeded in obtaining a description of the instruments in use at most of these stations, and copies of the Kew certificates having been kindly furnished by Mr. R. H. Scott, secretary of the Meteorological Council, we were able to correct the observations received for instrumental errors. The exposure, in many instances, seems to be objectionable, and the occasional visit of a Meteorological Inspector to all these stations would prove of great value.

In addition to the above, we have received a full year's return from the Scottish Missionaries at Kibwelzi. These returns include hourly observations for thirteen international term-days, and are by far the most complete received, up till now, from British East Africa.

Uganda.—Returns of the level of Victoria Nyanza, up to the end of July, have been received. The mutiny of the Sudanese unfortunately interrupted these valuable observations, but they have since been resumed.

Your Committee have decided to discontinue lending instruments, although they will always be pleased to advise as to purchase and use of them, and to prepare and publish results.

Having transferred the instruments in Nyasaland to H.M.'s Commissioner, and sold those formerly at Lambarene to M. Coillard, the only instruments still the property of the Committee are a set at Bolobo, on the Congo; a set at Kibwezi in East Africa; a set (probably injured beyond repair) at Wasi; an earth-thermometer in Uganda, and a rain-gauge at Golbanti. Lastly, a set of instruments, purchased to replace one lost by Mr. Herdman, is about to be restored to the Committee.

The abstracts appended have been prepared by the chairman of the Committee.

Your Committee propose that they be re-appointed. They do not ask for a grant, merely requesting authority to expend the 6*l.* received from the sale of instruments to M. Coillard.

Mombasa, 4° 4′ *S.*, 39° 42′ *E.*, 60 *feet.*
Observers: J. J. W. Pigott (to April 1896), *and C. R. Craufurd.*

Month	Pressure of Atmosphere 9 A.M.	Temperature Extremes		Mean Temperatures					Daily Range	Humidity			Rain		
		Highest	Lowest	Dry 9 A.M.	Wet 9 A.M.	Mean Max.	Mean Min.	Mean		Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall in 24 hours
1896	In.	°	°	°	°	°	°	°	°	°	In.	P. c.	In.		In.
January .	29·814	85·3	76·0	82·3	76·5	83·7	77·7	80·7	6·0	74·3	·847	77	·41	2	·36
February .	·839	85·6	76·4	82·1	76·2	84·8	78·1	81·4	6·7	74·0	·837	77	·00	0	—
March .	·821	87·3	78·4	84·2	78·2	86·4	79·6	83·0	6·8	76·0	·897	77	2·80	8	1·10
April .	·811	89·0	78·5	83·5	77·7	87·0	80·2	83·6	6·8	75·6	·884	77	2·08	12	·55
May . .	·894	86·8	74·9	80·5	75·0	83·9	77·5	80·7	5·4	74·3	·847	82	10·93	11	4·31
June. .	·951	84·8	72·4	78·3	74·4	83·1	75·0	79·0	8·1	72·9	·806	83	4·37	9	1·05
July . .	30·017	83·3	71·9	76·7	72·3	82·8	73·1	78·0	9·7	70·4	·743	80	2·77	8	·64
August .	30·002	86·3	70·9	77·0	72·8	83·3	72·8	78·0	10·5	71·1	·759	82	4·91	13	1·05
September	29·962	83·8	72·4	78·8	75·2	82·8	73·9	78·3	8·9	73·8	·832	85	2·05	9	·48
October .	·955	84·3	71·9	79·0	75·2	81·8	74·4	78·1	7·4	73·7	·830	83	2·39	7	1·00
November	·933	83·3	70·0	79·6	74·9	75·7	73·4	74·6	2·3	73·0	·811	81	27·67	12	4·28
December .	·870	85·3	70·0	81·2	77·7	79·7	74·3	77·0	5·4	76·5	·910	85	4·86	3	2·23
Year. .	29·906	89·0	70·0	80·3	75·6	82·9	75·8	79·3	7·1	73·8	·832	81	65·24	94	4·31
1897															
January .	29·879	86·3	72·9	82·9	81·3	83·3	75·4	79·3	7·9	80·9	1·053	94	1·00	2	·50
February .	·871	88·3	74·9	81·1	76·5	85·3	79·4	82·3	5·9	74·8	·830	81	·00	0	—
March .	·832	88·3	76·9	84·8	81·0	85·6	80·1	82·8	5·5	79·8	1·014	85	1·63	2	1·50
April .	·898	88·3	74·9	81·8	78·4	84·5	78·4	81·5	6·1	77·2	·933	86	15·42	10	3·95
May . .	·893	86·3	71·0	78·6	76·9	83·3	74·9	79·1	8·4	76·3	·904	92	25·40	10	5·50
June. .	·948	82·3	72·9	77·9	74·4	81·3	74·3	77·8	7·0	73·0	·811	85	·38	2	·34
July. .	·949	81·3	72·9	78·1	74·9	80·3	73·9	77·1	6·4	73·6	·828	86	2·78	1	2·78
August .	·987	80·8	73·1	77·6	74·1	80·1	74·9	77·5	5·2	72·7	·803	85	1·11	2	·65
September	·968	82·3	72·0	79·2	74·7	80·9	74·6	77·8	6·3	73·0	·809	83	1·51	8	·34
October .	·929	83·3	72·0	80·6	76·2	81·8	72·7	77·2	9·1	74·6	·854	83	2·82	3	2·30
November	·870	86·3	72·0	83·8	78·1	85·5	73·4	79·4	12·1	76·0	·897	78	·51	2	·26
December.	·827	86·3	72·0	82·3	76·9	86·3	73·1	79·7	13·1	74·9	·864	78	·00	0	—
Year. .	29·904	88·3	71·0	80·7	77·0	83·2	75·4	79·3	7·8	75·6	·886	85	52·56	42	5·50

The instruments in use are by Negretti & Zambra. The corrections for the Barometer (No. 1,564) are not known. The attached thermometer reads 0·40° higher than the dry bulb thermometer. Had we accepted the readings of the latter in computing the pressure, the difference would have amounted to only –·001 inches.

The thermometers were verified at Kew, in the dates mentioned below, and the corrections which had then to be applied to them were as follows :—

No. 4590 (dry bulb), September 1889 : up to 72°, 0·0 ; at 82°, +0·1 ; at 92°, +0·1.

No. 4596 (wet bulb), September 1889 : at 32°, –0·1 ; at 42°, 52°, 62° and 72°, 0·0 ; at 82° and 92°, +0·1.

No. 1358 (max. therm.) June 1890 : at 64°, –0·7°

No. 1458 (min. therm.), January 1891 : up to 32°, 0·0 ; at 32°, 42°, 52°, 62° and 70°, –0·1.

The instruments are placed in the Hall, under the Sub-Commissioner's office, 5 feet from the ground of the floor. The rain-gauge stands in the open space on the roof of the office.

No observations were recorded on Sundays (rainfall excepted), and in 1897 the office was closed also during Jubilee week (June 22–27) and Christmas week (December 25–31).

The barometrical observations have been reduced to 32° F., and to Standard gravity in Lat. 45°, but not to sea-level.

The mean temperature is assumed to be the mean of all max. and min., and is therefore too high.

Takaungu.* *Lat.* 3° 41′ *S., Long.*, 39° 52′ *E.
Observers:* *Ja. Weaver, Capt. E. Goldie-Taubman, J. W. P. McClellan, Ch. Wise, D. Wilson, and A. Rustomji.

Month	Rain, 1896			Rain, 1897		
	Amount	Days	Heaviest Fall	Amount	Days	Heaviest Fall
	In.		In.	In.		In.
January . .	0·00	0	—	·31	3	·15
February .	·00	0	—	—	—	—
March . .	·47	4	·25	1·24	7	·33
April . .	2·46	3	1·04	8·49	9	3·00
May . .	10·20	14	3·27	22·57	21	5·13
June . .	4·21	9	1·13	·80	8	·20
July . .	4·00	9	1·70	7·62	9	2·05
August . .	4·18	11	·88	3·35	13	·61
September .	·90	3	·39	2·17	13	·48
October . .	1·52	3	1·03	2·94	7	1·80
November .	19·24	17	3·13	—	—	—

Shimoni (Wanga), 4° 38′ S., 39° 21′ E.

Observers: D. Wilson, J. W. Tritton, D. Macquarie, J. W. McClellan.

Month	Atmospheric Pressure, 9 A.M.	Mean Temp. 9 A.M.		Humidity			Rain			Prevailing Wind at 9 A.M.								
		Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Cal.
1896	In.	°	°	°	In.	P.c.	In.		In.									
January	29·773	85·4	79·4	77·3	·936	77	·22	2	·18	—	11	4	2	—	4	—	10	—
February (1–17)	29·774	85·5	78·5	76·0	·895	73	·00	0	—	—	2	2	—	—	—	—	3	—
March	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
April (10–29)	29·797	82·3	79·7	77·8	·950	86	2·09	6	1·22	—	—	—	1	10	3	6	—	—
May	29·797	79·6	74·5	72·6	·800	79	12·64	23	2·43	—	1	—	—	13	18	—	—	—
June	29·805	78·1	75·0	73·8	·832	87	4·44	10	1·11	—	—	—	1	—	28	—	—	—
July	29·819	75·9	73·4	72·4	·794	89	2·60	16	·50	—	—	—	—	4	25	2	—	—
August	29·918	75·8	73·5	72·6	·799	89	5·24	16	·85	—	—	—	3	8	19	1	—	—
September	29·809	76·6	73·8	72·7	·801	87	2·35	8	·61	—	—	—	1	8	17	4	—	—
October	29·797	79·1	76·0	74·8	·862	86	·56	3	·28	—	—	1	3	16	8	3	—	—
November	29·791	79·1	76·8	76·0	·896	91	23·04	20	5·25	2	—	4	4	4	9	4	3	—
December	29·778	83·8	81·6	81·0	1·054	92	3·39	7	·87	3	3	16	2	—	3	—	4	—
Year	29·805	80·1	76·5	75·2	·874	85	56·57	111	5·25	5	17	27	17	63	134	20	20	—
1897	In.	°	°	°	In.	P.c.	In.		In.									
January	29·774	84·5	82·5	81·0	1·087	89	1·09	3	1·00	1	3	24	3	—	—	—	—	—
February	29·773	85·1	80·8	79·4	1·002	83	·00	0	—	—	1	27	—	—	—	—	—	—
March	29·770	85·0	82·4	81·6	1·076	89	2·37	7	·53	1	4	22	3	1	—	—	—	—
April	29·784	81·3	80·1	79·7	1·012	95	17·42	18	4·60	—	—	7	6	8	8	1	—	—
May	29·783	79·1	78·1	77·7	·949	96	19·96	23	4·00	—	—	—	—	8	19	1	3	—
June	29·802	77·7	75·9	75·2	·873	92	1·25	7	·38	—	—	—	—	16	14	—	—	—
July	29·808	76·9	76·1	75·8	·890	97	4·93	12	1·72	—	—	5	—	6	20	—	—	—
August	29·810	76·8	75·7	75·3	·875	95	3·45	17	·89	—	—	6	6	6	13	—	—	—
September	29·804	77·8	76·6	76·2	·901	95	1·29	7	·57	—	—	—	2	21	5	—	2	—
October	29·796	80·1	78·2	77·5	·942	92	2·27	8	·95	—	—	—	19	7	5	—	—	—
November	29·781	83·1	81·2	80·6	1·042	92	2·72	7	1·00	2	—	3	14	7	1	1	—	—
December	29·775	84·2	82·2	81·6	1·076	92	·00	0	—	7	—	11	—	9	4	—	—	—
Year	29·788	81·0	79·1	79·3	·977	92	56·75	109	4·60	11	8	105	53	89	89	3	5	—

NOTE.—The barometer is by Adie (M.O, 693). It was verified at Kew in December 1888, and the following corrections have to be applied to the readings:—at 29·5 in., —·004; at 30 in., 30·5 in., and 31 in., —·005.

The correction for the attached thermometer is +0·1.

The wet bulb thermometer is by Negretti & Zambra (No. 4576). It was verified at Kew in September 1889, when it was found that the correction for all readings over 52° F. was +0·1.

The rain-gauge, by Casella (No. 334), diam. 8 in., was found to be practically correct.

The recorded 'dry bulb' readings are from the thermometer attached to the barometer.

The instruments are exposed in a lime and stone room on the ground floor of the Government Office which has three large windows, and a stone ceiling. The rooms above have a galvanised roof.

The barometer readings have been reduced to 32° F. and Lat. 45°, but not to sea-level.

Lamu, 2° 16′ S., 40° 54′ E.

Observers: Capt. A. L. Rogers, K. Macdougall, W. B. Comyn, Chas. Faria (Postmaster).

Month	Mean Temp. 9 A.M.		Humidity			Rain			Mean Temp. 9 A.M.		Humidity			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall
	1896								1897							
	°	°	°	In.	P.c.	In.		In.	°	°	°	In.	P.c.	In.		In.
January	84·8	78·2	75·7	·888	74	·00	0	—	83·9	81·1	80·2	1·028	88	·03	1	·03
February	84·8	78·2	75·7	·888	74	·15	1	·15	83·6	81·4	80·7	1·046	91	·00	0	—
March	85·0	78·6	76·2	·903	75	2·10	3	1·55	84·8	82·0	81·1	1·060	89	·00	0	—
April	84·5	79·6	77·8	·951	81	3·33	8	1·23	83·0	82·4	82·2	1·099	97	14·73	13	8·25
May	81·7	77·4	75·7	·888	82	7·06	17	1·03	80·8	80·1	79·9	1·017	97	4·97	8	1·60
June	79·9	75·2	73·7	·818	83	8·63	17	3·57	79·2	76·6	75·6	·885	89	2·14	3	1·31
July	79·1	76·3	75·6	·885	89	1·66	9	·55	78·1	75·8	75·0	·865	90	4·14	7	2·17
August	78·7	75·0	73·5	·825	84	1·54	11	·46	78·7	75·4	74·1	·842	86	1·39	4	·69
September	78·5	74·3	72·6	·800	82	1·77	7	·44	79·2	75·6	74·2	·844	85	4·78	4	3·37
October	82·3	76·0	73·7	·829	75	·73	3	·36	81·1	75·8	73·3	·832	77	·00	0	—
November	81·6	79·0	78·1	·960	89	12·96	14	3·57	83·2	77·9	76·0	·886	79	·10	1	·10
December	83·6	80·5	79·5	1·002	88	1·36	2	1·16	83·7	80·5	79·4	1·004	86	·00	0	—
Year	82·0	77·4	75·7	·886	81	41·29	92	3·57	81·6	78·7	77·6	·951	88	32·28	41	8·25

The thermometers are exposed in the open Post Office. They were verified at Kew in September 1889, a the following corrections are to be applied to the readings:—

Dry bulb: Negretti & Zambra, No. 4,572: at all temperatures above 62°, up to 92°, +0·1.

Wet bulb: Negretti & Zambra, No. 4,573: at 62°, 0·0; at 72° and 82°, +0·1; at 92°, +0·2.

Malindi. Lat. 3° 13′ S., Long. 40° 7′ E. Observers: K. MacDougall, Jas. Weaver, J. W. P. McClellan, and D. Wilson.

Month	Mean Temperature 9 A.M.		Humidity			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall
1896	°	°	°	In.	P.c.	In.		In.
January	81·0	79·1	78·4	·971	92	·01	1	·01
February	80·6	78·9	78·3	·969	92	·00	0	—
March	87·4	84·5	83·6	1·150	88	·01	3	·10
April	86·1	83·6	82·9	1·122	90	4·37	12	3·10
May	82·1	77·5	75·8	·890	80	8·44	12	1·80
June	79·5	74·3	72·2	·789	78	6·07	10	1·33
July	77·8	75·1	74·0	·839	88	5·32	6	1·19
August	77·6	73·6	72·0	·783	83	1·50	6	·55
September	78·5	75·8	74·8	·860	88	5·01	15	·93
October	—	—	—	—	—	—	—	—
November	80·1	77·9	77·1	·930	91	21·20	16	4·36
December	81·9	78·1	76·7	·918	86	·67	5	·43
11 Months	81·1	78·0	76·9	·929	87	52·60	86	4·36
1897								
January	81·2	78·0	76·9	·922	87	·82	4	·70
February	81·8	77·1	75·4	·878	81	·00	0	—
March	84·5	79·4	77·6	·946	80	·58	4	·25
April	82·5	78·8	77·5	·941	85	16·80	16	4·85
May	79·8	77·6	76·8	·920	91	22·15	20	4·25
June	79·0	78·6	78·4	·971	98	2·05	6	·75

Kisimayu. Lat 0° 22′ S., Long. 43° 33′ E. Observer: R. G. Farrant.

—	Atmospheric Pressure 9 A.M.	Mean Temp. 9 A.M.	Rain		
			Amount	Days	Heaviest Fall in 24 hours
1896		°	In.		In.
January	—	82·1	·00	0	—
February	—	82·4	·00	0	—
March	—	84·4	·00	0	—
April	—	86·0	·07	1	·07
May	—	83·1	4·21	6	2·31
June	—	80·0	4·80	9	1·66
July	29·807	80·3	·51	6	·15
August	·937	79·6	1·85	13	42
September	·941	78·4	6·08	10	2·02
October	·948	81·8	·00	0	—
November	·940	82·2	1·97	8	·71
December	·934	84·5	·00	0	—
Year	—	82·1	19·49	53	2·31
1897					
January	29·939	83·3	·50	4	·40
February	—	83·0	·00	—	—
March	·794	84·3	.00	—	—
April	·877	84·1	5·50	6	3·16
May	·905	81·3	4·37	8	2·00
June	·928	79·4	4·18	8	1·10
July	·961	78·5	2·43	9	1·00
August	·988	78·3	2·02	5	1·60
September	·978	79·0	·95	3	·55
October	·939	82·0	·00	0	—
November	·884	83·1	·00	0	—
December	·856	82·0	·00	0	—
Year	[29·910]	81·5	19·95	43	3·16

Ndii. Lat. 3°20′ S., Long. 38°29′ E., 2,400 feet. Observers: Charles Wise, W. S. Godfrey, Captain E. Goldie Taubman, & O. Cordeiro.

Month	Mean Temperature 9 A.M.	Rain		
		Amount	Days	Heaviest Fall in 24 hours
1896	°	In.		In.
January	75·6	·10	2	·05
February	76·1	·63	3	·25
March	83·5	1·07	4	·61
April	80·1	2·61	6	·82
May	77·7	·83	4	·37
June	76·0	·00	0	—
July	75·0	·14	1	·14
August	73·5	1·76	4	·70
September	75·2	·00	—	—
October	76·7	·18	1	·18
November	75·1	6·85	12	1·70
December	76·1	9·72	15	2·45
Year	76·7	23·89	52	2·45
1897				
January	78·1	3·85	13	·60
February	80·0	1·24	2	·63
March	80·3	1·39	4	·56
April	82·6	6·58	14	1·50
May	75·5	4·56	16	·70
June	76·6	·58	4	·18
July				

NDII.—The thermometer and rain-gauge were supplied by the late British East Africa Company. These instruments are exposed 'on the ground in the middle of the station compound.' Corrections not known.

KISIMAYU.—The barometer (Adie, M.O. 691) was verified on Dec. 31, 1888, when the correction to be applied at pressures of 29·5 and 30·0 in. was found to be −·002. The attached thermometer at the same time needed a correction of +0·1°. The rain-gauge was practically correct.

The observations as now published have been corrected for instrumental errors, as they existed in 1888. The barometrical readings have been reduced to the standard temperature of 32°F, and to standard gravity in Latitude 45°.

Winds at Kisimayu.—The S.W. monsoons prevailed freely to October, 1896, when variable winds occasionally set in. The monsoon changed on the 29th of that month.

On May 17, 1897, between 4 and 6 A.M., a dense mist hung over the town and harbour.

Fort Smith.—The instruments at present available include two thermometers by Negretti & Zambra and a rain-gauge. The instruments were verified at Kew in March 1890 with the following results:—

Corrections to be applied to No. 4,634 (dry bulb): at 72°, −0·1; at 52°, 62°, 82°, and 92° the instruments read correct.

No. 4,635 (wet bulb) at 52° and 62°, +0·1; at all other temperatures correct.

The instruments are placed in an open verandah facing due west. They are 4 feet 6 inches from the ground.

In computing the Dew Point, &c., a pressure of 23·6 inches has been assumed.

Fort Smith, Kikuyu. Lat. 1° 14′ S., *Long.* 36° 44′ E., 6,400 *feet. Observers: T. T. Gilkison, C. R. W. Lane and Francis G. Hall.*

Month	Mean Temp. 9.30 A.M.		Humidity			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall in 24 hours
1896	°	°	°	In.	P.c.	In.		In.
January . .	65·8	62·8	61·5	·545	86	1·28	2	1·13
February .	68·2	63·4	61·4	·542	78	·35	2	·32
March . .	68·8	63·2	60·7	·530	76	1·74	8	·90
April . .	67·4	62·2	59·8	·514	77	3·89	14	1·04
May . .	64·8	60·9	59·1	·500	81	3·93	11	1·46
June . .	63·5	59·7	57·8	·479	82	3·41	5	1·73
July . .	58·8	57·3	56·2	·451	91	·47	5	·16
August . .	58·0	57·1	56·6	·458	95	1·64	7	·47
September .	65·8	63·5	57·0	·565	73	1·68	3	·89
October . .	—	—	—	—	—	—	—	—
November .	63·8	60·9	59·6	·509	85	8·83	20	1·52
December .	66·7	63·3	61·8	·551	84	2·29	8	·80
Eleven months	64·7	61·3	59·2	·513	83	29·51	85	1·73
1897								
January . .	70·0	63·1	60·0	·517	71	2·25	8	·87
February .	71·0	63·9	60·8	·531	71	2·59	7	1·12
March . .	70·6	63·6	60·5	·526	71	2·43	10	·91
April . .	66·5	63·4	62·5	·566	87	5·53	15	1·96
May . .	64·6	62·1	55·2	·535	71	5·53	11	·85
June . .	61·6	60·1	59·1	·500	92	2·02	4	·86
July . .	61·6	59·5	58·5	·490	90	3·82	3	1·37
August . .	61·3	59·0	57·8	·479	88	·99	2	·87
September .	61·9	59·2	57·9	·480	87	5·01	7	2·30
October . .	63·8	60·0	58·2	·484	82	1·67	5	·51
November .	64·4	61·1	59·5	·509	84	4·15	7	1·42
December .	65·8	61·6	59·6	·510	80	·32	2	·24
Year . .	65·3	61·4	59·1	·510	81	36·31	81	2·30

Machako's.—The thermometers in use, viz. Negretti & Zambra, Nos. 4,688 and 4,691, were verified at Kew in March 1890. No. 4,688 was found to give 'correct' readings. The correction for 4,691 at 62° is +0·1. At 52°, 72°, 82°, and 92° the readings are correct.

The thermometers are exposed in an open-air verandah facing west. They are about 5 feet from the ground. The rain-gauge stands on a parapet about 8 feet from the ground, and quite open.

In computing the Dew Point, &c., a mean pressure of 24·5 inches has been assumed.

[1] The record for January is stated to have been 'accidentally lost.' The rainfall is said to have amounted to 11 inches, of which 6·06 inches are said to have fallen on January 9. This would have been quite phenomenal, for in January 1894 only ·75 inches fell, and in January 1896 0·16 inches. At Kibwezi, during the same month, ·93 inches fell in 1896, and 4·58 inches in 1897. January 1897 seems, therefore, to have brought exceptionally heavy rains, but further information must be awaited before 11 inches can find a place in our returns.

Machako's, Lat. 1° 31′ S., *Long.* 37° 18′ E., 5,400 *feet. Observers, Charles R. W. Lane, John Ainsworth, L. L. Hinde, D. C. Macpherson.*

Month	Mean Temp. 9 A.M.		Humidity			Rainfall			
						Amount			
	Dry	Wet	Dew Point 9. A.M.	Vapour Pressure 9 A.M.	Relative Humidity 9 A.M.	Day 6 A.M. to 6 P.M.	Night 6 P.M. to 6 A.M.	Days	Heaviest Fall
1896	°	°	°	In.	P.c.	In.	In.		In.
January . .	68·5	64·2	62·2	·560	81	·00	·16	1	·16
February .	69·3	63·2	60·4	·524	73	·32	·04	2	·32
March . .	69·1	64·9	63·1	·576	81	·42	1·38	5	·50
April . .	68·4	64·2	62·3	·561	81	·75	2·91	9	1·60
May . .	67·2	62·2	59·8	·514	77	·00	1·32	4	·90
June . .	64·7	60·4	58·2	·485	79	·00	·07	1	·07
July . .	61·7	59·1	57·7	·477	87	·00	·00	0	—
August . .	62·1	59·1	57·5	·473	85	·00	·94	3	·68
September .	66·3	62·2	60·2	·522	81	·00	·00	0	—
October . .	68·0	63·2	61·0	·536	78	·95	1·89	7	1·38
November .	65·2	63·2	62·3	·561	90	3·99	8·01	26	1·80
December .	65·5	62·7	61·4	·543	87	1·07	1·70	15	·45
Year . .	66·3	62·8	60·5	·528	82	7·50	18·42	73	1·80
1897									
January [1] .	—	—	—	—	—	—	—	—	—
February .	68·8	65·2	63·6	·588	84	·29	2·38	11	·89
March . .	70·1	65·4	63·4	·583	79	·40	2·44	9	·52
April . .	67·8	63·8	62·0	·555	82	1·00	10·01	20	1·80
May . .	66·4	62·7	60·9	·535	82	·03	2·66	9	·90
June . .	62·4	59·5	58·0	·481	85	·25	·63	4	·30
July . .	62·2	58·7	56·9	·462	82	·50	·55	2	·70
August . .	62·8	58·4	56·0	·448	78	·80	·45	3	·80
September .	67·1	63·4	61·7	·549	83	·59	·54	4	·47
October . .	67·6	66·7	66·4	·646	96	·21	3·67	8	1·20
November .	67·6	66·5	66·0	·639	93	·32	3·66	8	1·50
December .	69·1	65·2	63·6	·586	83	·12	·20	1	·32
Eleven months	66·5	63·2	61·7	·552	84	4·51	27·19	79	1·80

Kibwezi. *Lat.* 2° 25′ S., *Long.* 37° 55′ E., 2,990 *feet.* *Observers: Rev. Matthew Wilson and John Paterson.*

1897	Pressure of Atmosphere			Mean Temperature						Temp. Extremes		Mean Temp.: Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain		
	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Mean Max.	Mean Min.	Mean	Highest	Lowest	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall 24 hours
	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	P.c.	P.c.	P.c.	In.		In.
January .	26·956	26·889	26·919	67·6	81·5	67·3	85·7	63·0	70·9	92·5	56·5	67·4	75·0	67·1	67·3	72·6	67·0	·668	·801	·661	99	81	99	4·58	8	1·74
February .	26·945	26·858	26·906	67·7	87·3	69·4	92·1	62·1	73·5	99·0	56·5	66·5	77·3	67·8	66·1	73·9	67·1	·637	·835	·663	94	72	94	·93	5	·81
March .	26·943	26·923	26·932	69·6	89·9	72·3	94·9	65·1	76·0	98·2	58·0	68·3	74·0	68·5	67·8	67·8	66·8	·679	·679	·657	94	60	88	·96	3	·63
April .	26·948	26·928	26·939	67·6	85·5	70·7	90·3	62·8	73·6	98·7	58·0	66·9	74·5	68·5	66·6	70·4	67·6	·651	·742	·673	97	70	91	3·23	14	·60
May . .	26·959	26·934	26·949	65·8	82·9	69·0	87·5	60·0	71·7	94·7	55·2	65·6	73·5	67·0	65·5	70·0	66·1	·627	·730	·641	99	73	93	1·83	7	·95
June. .	27·024	26·955	27·003	63·0	81·5	67·7	86·0	55·9	70·0	94·5	51·0	61·6	70·5	63·8	60·8	65·8	61·9	·533	·634	·552	92	69	87	·01	1	·01
July .	27·020	26·961	27·000	62·4	81·7	66·9	86·6	55·4	69·5	92·2	48·5	61·5	69·7	64·7	61·0	64·4	63·6	·536	·605	·588	96	67	92	·00	0	—
August .	27·040	26·933	27·005	61·9	82·9	68·7	86·1	55·6	70·6	91·5	50·0	59·9	69·2	64·1	58·8	63·0	61·8	·495	·575	551	90	64	86	·00	0	—
September	27·017	26·939	26·986	63·5	85·0	69·6	88·8	57·6	71·9	94·5	49·7	62·1	69·8	65·1	61·4	63·0	62·9	·543	·575	·573	92	61	86	·54	3	·31
October .	27·009	26·916	26·973	66·2	85·9	71·7	88·9	62·6	73·9	96·2	57·0	65·0	71·1	67·0	64.4	64·8	64·9	·604	·612	·614	94	61	85	2·14	6	1·23
November	26·958	26·866	26·918	67·7	84·4	74·3	88·6	64·4	75·2	95·5	61·0	66·9	73·8	70·4	66·6	69·8	68·8	·650	·726	·703	95	71	87	6·36	11	2·63
December.	26·954	26·858	26·909	67·6	86·4	68·5	90·1	59·3	72·8	94·2	55·0	66·4	72·9	64·5	65·8	67·5	62·6	·635	·672	·566	94	64	87	·93	5	·73
Mean .	26·978	26·913	26·953	65·9	84·6	69·7	88·8	60·3	72·5	99·0	48·5	64·8	72·6	66·5	64·3	67·7	65·1	·604	·683	·620	95	67	89	21·51	63	2·63

The following are the instruments in use at the Scottish Mission Station of Kibwezi, with the corrections applied to the Readings :—

Barometer, Adie, B.T. (Kew pattern) No 782. Correction :—·005 in. throughout. Attached thermometer, correction at 52°, −0·4°.

Maximum Thermometer Negretti & Zambra, No. 75,244. At 22°, −·02 ; at 32° and 42°, −·01 ; at 52° and 62°, −0·0 ; at 72°, −0·1 ; at 82° and 92°, −0·0.

Minimum Thermometer, Negretti & Zambra, No. 73,908. At 32°, −0·1 ; at 42°, 52°, and 62°, −0·0 ; at 72°, −0·1.

Hygrometer, with copper water vessel, by Casella :—

Dry bulb, No. 90,805, at 52°, 62°, 72°, 82°, and 92°, −0·1.

Wet bulb, No. 90,806, at 42°, —0·0 ; 52° to 82°, −0·1 ; at 92°, −0·2.

The barometrical observations have been reduced to 32° F., and to Lat. 45°, but not to the sea-level.

The mean temperature is assumed = ¼ (7+2+9+9).

Variations in the Level of Victoria Nyanza.

Decades 1897		Lake Level			Rain		
		Port Alice noon	Lubwa 9.30 A.M.	Port Victoria 9.30 A.M.	Port Alice		Port Victoria
					Amt.	Days	Days
		In.	In.	In.	In.		
January,	I.	−3·00	−3·51	−3·53	·08	2	1
	II.	−2·70	−2·51	−2·11	·47	2	5
	III.	−1·90	−2·57	−1·93	1·20	2	0
February,	I.	−3·00	−1·53	−1·58	1·21	7	6
	II.	−2·00	− ·83	·20	·59	3	2
	III.	−1·70	−1·99	− ·47	1·82	3	1
March,	I.	−1·70	−1·13	− ·23	1·08	2	2
	II.	−1·30	−2·03	− ·08	·97	5	3
	III.	−1·55	−2·02	·79	1·92	9	3
April,	I.	·05	− ·78	1·02	1·94	7	7
	II.	1·40	1·47	3·77	7·43	10	5
	III.	3·10	2·87	5·00	4·37	9	4
May,	I.	4·65	4·17	4·57	1·67	7	5
	II.	4·95	4·60	1·42	1·51	6	1
	III.	6·85	3·75	1·42	7·37	9	6
June,	I.	7·30	4·57	4·67	1·46	5	6
	II.	7·10	7·10	7·02	·26	1	5
	III.	5·40	5·60	5·12	·45	2	3
July,	I.	4·85	5·09	4·67	1·05	3	1
	II.	4·50	1·72	3·92	·62	3	2
	III.	3·68	4·50	4·52	1·22	4	3

Notes.

The observations at Port Alice were made by Mr. Fred Pordage, at Lubwa's by Mr. W. H. Wilson, and at Port Victoria by Mr. C. W. Fowler. For the position of these stations see the Sixth Report, for 1897.

All observations are referred to the mean lake-level at each station for the year 1896.

On comparing the Results for 1897 with those for 1896 it will be found that during the last decade of July the lake-level was 3·27 in. higher than during the corresponding decade of 1896, and this notwithstanding that on January 1, 1897, the level of the lake stood 3·6 in. below the Datum level, whilst on January 1, 1896, it stood 7·8 in. above it. This difference in level is due to the heavier rainfall of 1897.

The lake was lowest in the beginning of the year, highest in June. The extreme range during the seven months for which records are available amounted to 8 in. at Port Alice, to 9·7 in. at Lubwa's, and to 7·5 in. at Port Victoria.

For remarks on the conditions governing the rise and fall of lake, see last year's Report.

Correction: In column 5 of last year's table, instead of 15·40 *read* 1·54.

Months	Mean Lake Level			Fluctuations[1]			Rain Fall Port Alice	
	Port Alice	Lubwa	Port Victoria	Port Alice	Lubwa	Port Victoria		
1896	In.	In.	In.	In.	In.	In.	In.	days
January	−2·00	−2·85	−2·50	2·50	2·50	2·75	1·75	5
February	−2·20	−1·45	− ·77	2·00	4·00	3·00	2·62	13
March	−1·16	−1·73	− ·18	1·50	4·75	1·50	3·97	16
April	1·52	1·19	3·26	5·00	6·00	5·00	13·74	26
May	5·18	4·16	2·44	2·00	4·00	6·00	10·55	22
June	6·60	5·76	5·60	3·50	5·75	4·50	2·18	8
July	4·32	3·94	4·37	1·50	5·75	2·00	2·89	10

[1] That is, difference between the lowest and highest level during each month.

The Mechanical and Economic Problems of the Coal Question.

By T. FORSTER BROWN, *M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso.*]

WITHIN the limits of a Paper it is practicable only to touch upon some of the more important of these problems; and the writer would refer those who desire to investigate more fully the economic side of the question to Prof. Jevons' work, 'The Coal Question,' Prof. Hull's 'Coal Resources at the Close of the Nineteenth Century,' Mr. Leonard Courtney's Address to the Statistical Society in December, 1897, a Paper by the present writer read before the Economic Section of the British Association in 1891, and 'The Coal Supplies of the World,' by Mr. Benjamin Taylor, a Paper published in the July number of the 'Nineteenth Century.'

To discuss all the suggestions as to substitutes for coal which have been made from time to time, up to and including the present meeting of the British Association, would require an exhaustive paper on that subject alone; but it is confidently submitted that so long as coal can be produced at a moderately cheap cost, having regard to the carbon it contains, it will always remain by far the most economical and convenient of power producers.

Coal Resources.

It is general knowledge that our coal resources extend over wide areas in several parts of this kingdom in beds or seams of varying thickness and quality existing at various depths below the surface, and generally situate at no great distance from the seaboard; and it may be assumed that the public are also aware that the most available and valuable of these resources are the first to be attacked and exhausted. The coal seams which are workable by free drainage levels, without pumping or winding, are naturally the first to be worked in a virgin coalfield; and such resources as these were probably the main source of our coal supply up to about the middle of the present century. Next follow the best of the thick seams of coal accessible at a reasonable depth, varying from a few yards to two thousand feet or thereabouts; and these resources, which were originally much larger than they are now, are, and will be for a considerable time, the principal source of our coal supply; and, lastly, the thin and inferior seams existing at shallow depths, and all the seams below two thousand feet or so down to the extreme limit of workable depth, and these larger resources are still practically intact.

It is difficult to induce the public to realise the supreme importance of the fact that it is only the best and cheapest of our coal resources which supply our existing output. The writer has pointed out in a previous paper that, without some great and radical change in our internal policy, applied to counteracting an increasing cost, the amplitude of the total estimated coal resources and their duration is not the probable true limit, in time, of our commercial supremacy; for, under ordinary circumstances, this will be measured by the duration of the best and cheapest of our coal resources only, and from which we now derive probably 95 per cent. of our annual coal outputs.

It is suggested that the position in figures, adopting Professor Hull's estimate of the total coal resources of the kingdom in seams of two feet and upwards in thickness, and existing at depths below the surface not exceeding four thousand feet in the year 1900, would be . 81,683,000,000 tons

And deducting from this quantity the writer's estimate in 1900 of the resources of best coal remaining within a depth below the surface of two thousand feet, about the limit probably of cheaply worked coal . . . . 15,000,000,000 „

Leaving approximately . . . . 66,683,000,000 „

of best coal existing between a depth of two thousand and four thousand feet below the surface, and of thin and inferior seams at all depths to the limit of four thousand feet.

Allowing for a small gradual increase of output from deep and inferior seams during the next fifty to sixty years, and assuming an average output for fifty years of best coals within a depth of two thousand feet at 220,000,000 tons per annum, exclusive of thin and inferior seams, we shall have exhausted eleven-fifteenths of our best resources about the year 1950, and have arrived at a stage when our whole annual output will be composed of a rapidly-increasing proportion of deep, thin, or inferior coals, and the proportion of our cheapest-worked coals will rapidly decrease.

It will be apparent, however, that at the end of fifty years we shall still have coal resources remaining, workable, it is true, at a gradually increasing cost, but sufficient for the supply of the nation at an average output of 250,000,000 tons a year for upwards of a period of 250 years.

But in working this very large residuum a greater cost in working, due to natural causes, is inevitable; and that this extra cost will gradually increase year by year after the best and cheapest coals are exhausted is undoubted, however successfully the skill of the mining and mechanical engineer may be brought to bear in mitigating this effect, and unless additional measures can be adopted, outside the province of the engineer, to counteract it by cheapening the carriage of the coal on the surface, and reducing materially all other charges, such as labour rates and taxes, &c., the effect of this increasing cost will be of serious moment to the nation.

The fact of the coalfields of Great Britain being situate at no great distance from convenient ports and home centres of consumption has had, and will continue to have, an important bearing upon the rapid development of our coal resources, and adds immensely, of course, to the intrinsic value of our coal resources as a whole.

The general cost of our coal will, of course, increase in proportion to the percentage of thin and deep coal worked to the whole annual output, until the increased cost of the whole of our coal production due to natural causes, such as depth, thinness of seams, &c. (however much this may be neutralised by improved mechanical and mining appliances), will be so increased as to seriously and permanently hamper our progress commercially by increasing the cost of our home manufactures and steam shipping, increasing the cost of navigating our steamers, and lessening thereby the amount of our coal exports, increasing also the cost of our imports of raw material and food supplies, and generally gradually taking from us for the benefit of other nations our home and foreign trade.

The progress of this item of increased cost of our coal may be gradual and comparatively imperceptible for fifty years, or thereabouts, owing to the continual development of the unopened portions of our coalfields and the resources of good and thick seams still unworked in existing collieries, but after fifty years or so this progress will be much more rapid.

It will now, therefore, be convenient to consider in what direction it may be practicable to improve our existing appliances for working coal, and otherwise reduce the cost of working deep and thin seams of coal in the future.

This naturally divides itself into, first, the improvements which may be achieved by the mechanical and mining engineer, and, secondly, what changes in our charges for transit and other items of cost which come more properly within the province of the Economist than the Engineer, are possibly practicable.

Dealing first with the improvements which may be effected by the mechanical and mining engineer, these may be divided into—(*a*) improvements which may be effected equally applicable to existing collieries and future coal mining; (*b*) improvements which can be effected applicable especially to the working of coal from great depths.

Under the head of (*a*) we have—

1. Mechanical application of machinery for cutting thin seams and exceptionally hard thick seams.
2. Improvements which may be effected in underground haulage.

1. *Coal-cutting Machinery.*

Machines may be classed as below:—

(*a*) Heading machines.
(*b*) Machines adapted for working in headings or 'rooms.'
(*c*) Machines adapted for continuous 'longwall' faces.
(*d*) Percussive drills mounted on wheels for use in headings, rooms, or 'longwall' faces.

2. *Improvements which may be effected in Underground Haulage.*

This comprises primary and secondary haulage: primary comprising the haulage between the bottom of the shaft and points upon the haulage roads, within a varying but moderate distance from the working coal face, and secondary haulage being the conveyance of the coal between these points and the working face. The writer sets out the various systems of haulage, and states the cost of primary haulage to be from 2*d.* to 4*d.* per ton per mile. Secondary haulage the writer suggests improvements in, and states the present cost is from 1*s.* 2*d.* to 1*s.* 8*d.* per ton per mile.

Improvements which may be effected, applicable especially to Working Coal from Great Depths.

Namely:—(1) Winding and Pumping; (2) Ventilation; (3) Dealing with high temperatures.

1. *Winding and Pumping.*

The mechanical difficulties arise chiefly in the design of winding engines. Special winding plant and appliances associated therewith are required for producing large outputs from an increased depth to compensate for the heavy increase in capital outlay, and in loss of interest due to the extra time required in establishing a deep winning.

Of late years much progress has been made in new coal winnings, in improvements in winding engines by compounding, balancing, and in some cases condensing, and in the quality of the wire ropes; and in the future it is suggested that progress must be looked for in the application of compound engines, working with a separate condenser, raising heavier loads at a higher piston speed, but with somewhat smaller drums, with a balance rope somewhat heavier than the winding rope, to assist in starting the load from the bottom and arresting the load as it arrives at the surface. The writer gives further details as to improvements practicable.

Experience has shown that except under special circumstances, such as the workings approaching the Millstone Grit or Mountain Limestone, porous rocks underlying the Coal Measures, feeders of water in the Coal Measures proper at great depths are rare, and pumping water, although very expensive, will not materially operate in increasing the cost of deep coal mining.

2. *Ventilation.*

So far as the obtaining of a sufficient quantity of air for ventilating deep mines is concerned, no difficulty exists. The higher temperature, provided the shafts and air roads in the mines are large enough, will rather facilitate the supply of air. Improvement in useful effects in the exhaust fans which are now nearly universally employed for ventilating deep mines is practicable.

3. *Increase of Temperature due to Depth.*

This is a most serious obstacle to deep mining. It is well known that the temperature of the stratification increases with depth at the rate of about one degree Fahrenheit in every 60 feet, and adopting this ratio we reach a temperature of 91° at 2,500 feet, 99° at 3,000 feet, and according to Professor Hull the temperature at a depth of 4,000 feet will be 116°. And manifestly, inasmuch as in deep mining it will be necessary to take precautions against explosions by damping the dust and otherwise creating a certain amount of moisture in the atmosphere, which further increases the high temperature difficulties, it is difficult to see how coal, even at from 3,000 to 4,000 feet, can be worked without great increase in the cost due to the reduced amount of work which can, at a high temperature, be performed by manual labour.

It has been suggested that the difficulty may be overcome by artificially cooling the air admitted to the mine, but the immense volume of air necessary in a deep colliery, probably from 300,000 to 400,000 cubic feet per minute, and the rapid rate at which after cooling, in passing along the passages of the mine, the temperature increases, render any application of the freezing process, as far as present appliances go, out of the question.

This process may, however, be practicable for cooling the smaller currents of air required in very deep metalliferous mines.

It has, however, been observed that in longwall working, as compared with pillar and stall working, the temperature of the air does not rise so rapidly owing to the fact that the current in its progress through the mine does not come into contact with so much of the strata, and in passing through long passages in a mine, the air has a tendency to cool the exposed surface of the passages, and so reduce the heating effect of the sides of the passages, and the writer suggests that a very material and possibly sufficient reduction of temperature may be looked for even to a depth of 4,000 feet, if the present practice in the best modern deep collieries is adopted of not only working the coal 'longwall' and upon the Midland system of few passages near the face of working, but systematically packing the spaces from which the coal has been excavated, thus reducing the parts of the mine exposed to the currents of air to the lowest practicable limit, namely the air passage and simple working faces; and by carrying the intake airways as direct as possible to the point of working, and making the working face in as straight a line as practicable, it may be possible to reduce the natural temperature of the stratification alongside the air passages at from 3,000 to 4,000 feet in depth in this way by from 15° to 25° Fahr.

Even at this reduced temperature, which would mean over 90° at 4,000 feet in depth, labour cannot be applied without considerable difficulty; but it would be apparently possible at all events to work the best of the seams at this depth at an increased cost.

Practically, in the absence of any mechanical process for artificially cooling the air at the point where it is required to be used in the working face, the alternative suggested may be effected if the air passages and currents of air are made large enough, and the sides of the passages and the gob or excavated spaces as far as practicable sealed up.

Before dealing with the second question, namely: What changes in our charges for transit and other items of cost are possibly practicable? it may be of interest to review shortly the general progress of coal mining in this and other countries at the present day.

Taking Great Britain to begin with, the cost of working coal has even at the present time under existing conditions a tendency to increase. This is chiefly due to the greater cost of labour and the extra charges for rates and taxes. The first item is undoubtedly increasing, and this is not altogether due to less work being performed by the workmen for a given wage, but partly to the cost of larger staffs and improved appliances to meet the requirements of the various Coal Mines Regulation Acts; and whilst the precautions required by these Acts undoubtedly have added to the expense of working, they have also resulted in the saving of life, and, therefore, so far as this charge adds to the cost, it is an addition which cannot be a subject of regret to the community. There has also latterly been a gradual tendency to an increase in rates and taxes, which are now a very serious impost on coal mining, and, unfortunately, in the mining districts where the coal-owners are the largest ratepayers, they have little or no control over the expenditure of the proceeds of local rates.

This item of rates and taxes is, in fact, growing without check, and unless something can be done to stop wasteful expenditure, it is likely to be a most serious charge upon coal mining in this country.

Then again, a further addition to the cost is imminent by reason of the Workmen's Compensation Act. And some increase is also caused by thin seams now being worked in some of the smaller districts where the thick seams have been exhausted.

Then also some deeper pits have been opened with perhaps a higher average cost, due to depth; in fact natural causes have begun to operate to a small extent.

On the other hand, considerable economies have been achieved within the last twenty-five years by using high pressure steam, a better class of boiler, economisers for using highly-heated water for boilers, increased outputs from existing mines, reducing the cost of the staff and appliances, improved methods of underground working, better realisation of the by-products from the coke, improved ventilation and precautions for dust laying, reducing the number and risks of explosions ; and in some districts, such as South Wales, material reductions in railway carriage have as the result of competition been achieved within that period.

So that to summarise the position of the cost of working, whilst considerable economy has been achieved in some directions, natural, physical and other difficulties have increased the cost of working coal in Great Britain.

So far, however, as the Western Hemisphere is concerned, similar conditions will probably more or less apply to the German coalfield, and elsewhere in Europe—*i.e.* the costs of production in these countries will have a tendency also to increase slowly.

In the case of Germany, our main European competitor, the railway and canal rates for minerals are, per ton per mile, the writer believes, already much below the rates prevailing in this country, and therefore there is not the margin for future reductions in these rates which ought to exist in Great Britain, where the railways are not as yet the property of the State. And in regard to our competition with European coalfields, taking Germany as possessing probably the largest and most accessible coalfield, the conditions of greater depths and higher costs will be likely to either immediately follow or precede the operation of the same causes in Great Britain ; but the competition we have to fear in the Western Hemisphere is that of the United States of America.

There coalfields exist of enormous extent, twenty times the original areas of our coalfields, and already the cost of producing coal in America is below the cost of raising coal in Great Britain. The annual production in the States is proceeding by leaps and bounds.

In 1883 it was 102,868,000 tons ; in 1890 it was 140,883,000 tons ; and in 1896 it was 171,416,000 tons.

Mr. Courtney contends that lesser cost of production in America will be permanently operative, and the difference in favour of that country is likely to increase. Probably this is so, in some degree, but the immediate cause of the difference in favour of the States as against Great Britain is due chiefly, the writer suggests, to the enormous extent of the American coalfields, making it practicable to work very large annual quantities from those areas near the outcrop by free drainage levels, without pumping or winding ; in fact the States as regards their facilities for raising coal cheaply are much in the position Great Britain was fifty to sixty years ago.

If the coal output of the United States continues to increase in the present ratio, the time will arrive, no doubt, when shafts must be sunk to considerable depths and pumping and winding resorted to, thereby increasing the average cost, and bringing the natural conditions in that country more in line with those which prevail in this country.

The enormous extent of outcrop coal in the American fields will, however, enable that nation to maintain probably for many centuries a comparatively low cost of working.

The States coalfields moreover, although generally distant from the Atlantic seaboard, by reason of the cheaper capital cost of the American railways and better application of the rolling stock for mineral traffic, such as wagons carrying a very much larger proportion of profit load to deadweight and long leads, are able to convey coal at about one-quarter of the cost per ton per mile which the best and most economically worked of our English railways now charge to convey minerals in this country. Fortunately for us the American coalfields are situate some distance from the Atlantic seaboard. It is true that in regard to the item of deadweight our railways could also in this country considerably reduce their costs by increasing the size of their mineral wagons, but there exist again other possibly more serious competitors even than America, which may ultimately shut out the whole of the Eastern markets for manufactures both from Europe and America—namely, China and Formosa. In China enormous coalfields are believed to exist containing coals of the best qualities, and only requiring capital development in railways and docks and manufactures to enable it to become the greatest of our future competitors, and to develop an extraordinary source of wealth. The extremely low cost of labour alone will probably handicap the Western nations to an extent which at present cannot be measured, and whether the period when this competition will be seriously felt is distant, or imminent, the fact itself of these coalfields existing in a country densely populated by a clever and industrious race should enforce the lesson to Great Britain of setting her house in order. The argument may be even stronger as regards the coalfields of Formosa,[1] under Japanese rule, of which less is known, but where probably coal will be found near the seaboards and in a parallel position, as regards facilities for export, to our own coal deposits.

Summarising the position, some portion of the increased future cost of working our coalfields can and will be met by improved mechanical appliances in winding, hauling, pumping, and in cutting thin seams, and by mining skill in improved ventilation, lighting, checking the increase of temperature due to depth, raising larger quantities from each shaft, and a partial readjustment of the cost of labour and royalties.

The last named are already in process of being dealt with when the conditions require it (*see* the Mining Royalty Commission Report of a few years ago); but there will still remain a growing margin of increased cost which cannot be dealt with either by the mechanical or mining engineer.

There remains the question, therefore, What can be done in other directions to counteract the inevitable increase of cost in working? The writer suggested in 1891, and now repeats that proposal with even greater force, the time available being lessened by seven years, that the nation should take the necessary steps now when it is practicable to acquire the reversion of railways and docks, to enable the cost of railway carriage for minerals, goods, and passengers, and dock dues to be ultimately reduced if required to the bare cost of working.

All capital invested in drainage, water, lighting, schools, parks, &c., ought to be also repaid within the next sixty or sixty-five years, to admit of a permanent reduction in the incidence of rates and taxes.

Assume for the moment that this country were in the position of, say the Continental States, in regard to the railways belonging to the State, that all the capital expended upon railways, docks and harbours, water, gas and electric lighting, and in all public improvements, &c., belonging

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[1] Mr. Warington Smyth informs me that there are few, if any, convenient harbours in Formosa, that on the eastern part of the island there exists a range of high mountains, and on the western side the sea is very shallow for a great distance from the coast.

to public bodies had been repaid. If this were so the State could reduce the cost of carrying minerals, goods, and passengers nearly 50 per cent., the rates and taxes would be lessened, and the cost of living greatly reduced, lessening the cost of labour, and making this kingdom from its temperate climate perhaps one of the pleasantest and most economical of residential countries in the world.

The reductions in the rates of carriage of minerals and goods, and in dock dues and terminal charges, and in rates and taxes, would with mechanical and mining improvements probably so neutralise the gradual increase of the cost of our coal as to enable our coalfields to maintain their position as competitors with the Western Hemisphere for probably another two and a half centuries. We should be able also to maintain our Army and Navy, and the cheap living cost would facilitate the gradual and successful introduction of industries requiring much labour, and the nation would have that long period in which to complete the repayment of the National Debt.

The paying off of the National Debt now in progress is undoubtedly a commendable operation of itself, but if we are to suffer collapse commercially in half a century, or thereabouts, if the whole debt were paid off in the meantime the relief would only be temporary, but if on the other hand a similar annual sum to that applied to the repayment of this debt, or more, if required, were set apart for purchasing the reversion of the railways, &c., and providing legislative means of checking and raising of capital for public purposes, except with stringent provisions for repayment, then the nation would have ample opportunities left of paying off the National Debt in the future, after these other and more imperative economies have been provided for.

If we look for a moment at the reverse side of the picture, and assume that the nation will do nothing to guard against the danger of commercial collapse which will take place upon the exhaustion of our cheaply-worked coal resources, we shall be in the position of being saddled with the large amount of capital invested in railways, docks, and public works, amounting, it is estimated at the present time, to approaching 1,500 millions of money, with no opportunity of paying off this capital.

The cost of our manufactures will rise, our foreign markets will in consequence be curtailed, resulting in a large proportion of our population being thrown out of employment, our income and means of supporting our Army and Navy will rapidly decrease, and Great Britain must gradually sink to the position of a secondary power.

Existing and immediately succeeding generations, therefore, cannot be justified, under the circumstances of the enormous advantages they are receiving, and will for half a century yet receive, from the working of the most valuable portion of our coal resources, in neglecting to adopt some well-considered and comprehensive scheme for dealing successfully with the inevitable future difficulties indicated with the great object of extending the duration of the prosperity of this nation far into futurity.

A New Instrument for Drawing Envelopes, and its Application to the Teeth of Wheels and for other Purposes. By Professor H. S. Hele-Shaw, *LL.D., M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso.*]

The present paper is divided into two parts, the first dealing with a description of the various forms of the new instrument, the second dealing with the various examples of its use as a trammel for drawing curves, and of its application for various purposes, such as the teeth of wheels, blowers, and other revolving bodies where more or less accurate contact is required, necessitating the formation of an envelope to a curved outline previously described.

A communication which may be regarded as supplementing the present paper has been read in the Mathematical Department of Section A (see p. 136), dealing with the applications of the instrument for the construction of cycloids and involutes, and for the drawing of ellipses and other curves.

Some time ago the author devised an arrangement for exhibiting to his students the envelope of any plane figure revolving about a fixed axis upon another revolving surface, the two rolling together upon a pair of imaginary pitch circles. This arrangement merely consisted of two sheets of paper turning on drawing pins as centres, while a small wheel, with a number of projecting needle points on its edge, simultaneously engaged both sheets of paper, thereby compelling them to revolve together. This wheel of course was really in contact with the two imaginary pitch circles.

It was then seen that it was not necessary to employ the actual pitch circles, as auxiliary circles would serve the same purpose and would not necessitate the paper or cardboard being actually punctured by the small needle points. Moreover, the circles were formed separately on each sheet so long as the respective wheels were connected by one axle, and narrow-milled rollers could be used instead of the roller with needle points. What was more important, the space left when parts of the surface cutting the pitch circles, such, for instance, as the spaces in tooth gearing were actually removed, did not prevent the continuous rotation of the two sheets of paper. A pencil outline round the boundary thus left could be drawn in a number of positions close to each other, thereby giving the required envelope for the corresponding teeth required to gear with those originally formed.

Fig. 1 shows the instrument, which had two pairs of roller or disc wheels (connected by one axle), one above and one below the moving surfaces of the cardboard.

With this instrument very little slip took place, and it was found that students could easily use it without having had any previous experience.

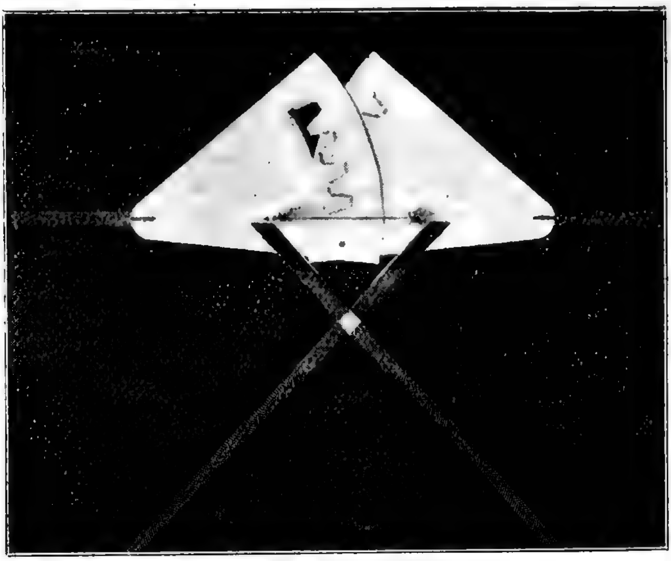
There are three ways in which a given curved outline of any form working about a fixed centre could be obtained.

(1) By stencilling in the outline of the revolving sheet beneath.

(2) By photographs, when the two surfaces moved over one another with a fairly rapid movement.

(3) By placing the original curve above the other in a series of consecutive positions, and in each position drawing round the outline with a pencil or pen.

FIG. 1.



This latter method proved to be by far the most satisfactory, and fig. 2 gives one or two examples of the mode in which the outline of the required envelope is thus produced.

FIG. 2.

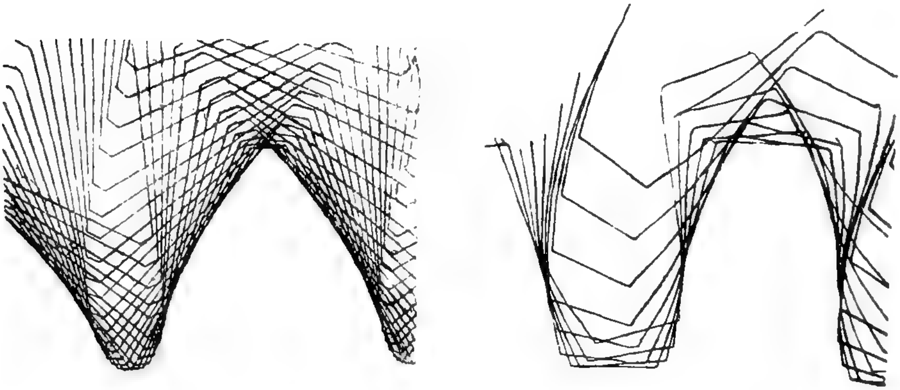


Fig. 3 is a more compact form of the instrument, in which, in order to obtain circles of different diameters, a sliding centre was used.

In these cases there is a certain amount of inconvenience from the axle of the upper pair of edge runners, and although the frame was inclined, yet the axle itself prevented the curve being conveniently drawn, and the arrangement, shown in figs. 4 and 5, indicate the method by which the necessary driving shaft could be kept entirely beneath the surface of the paper, and by the use of an equal pair of spur wheels the upper axle is done away with.

FIG. 3.

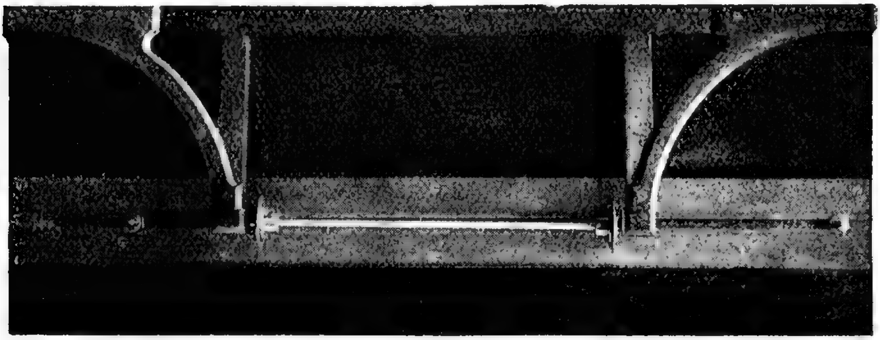


FIG. 4.

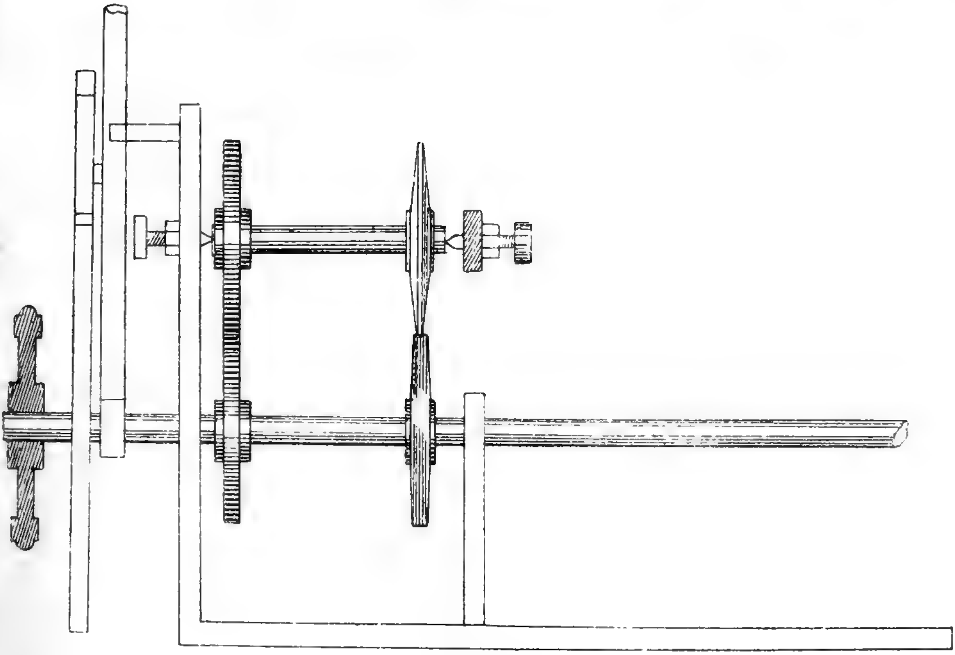
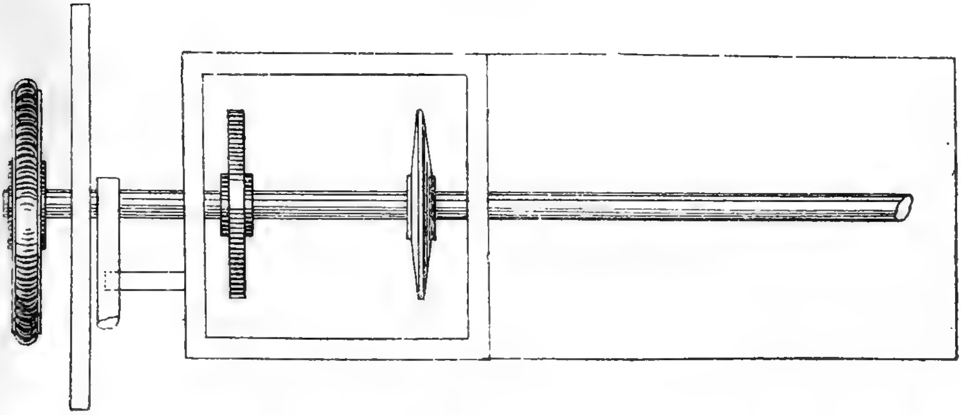
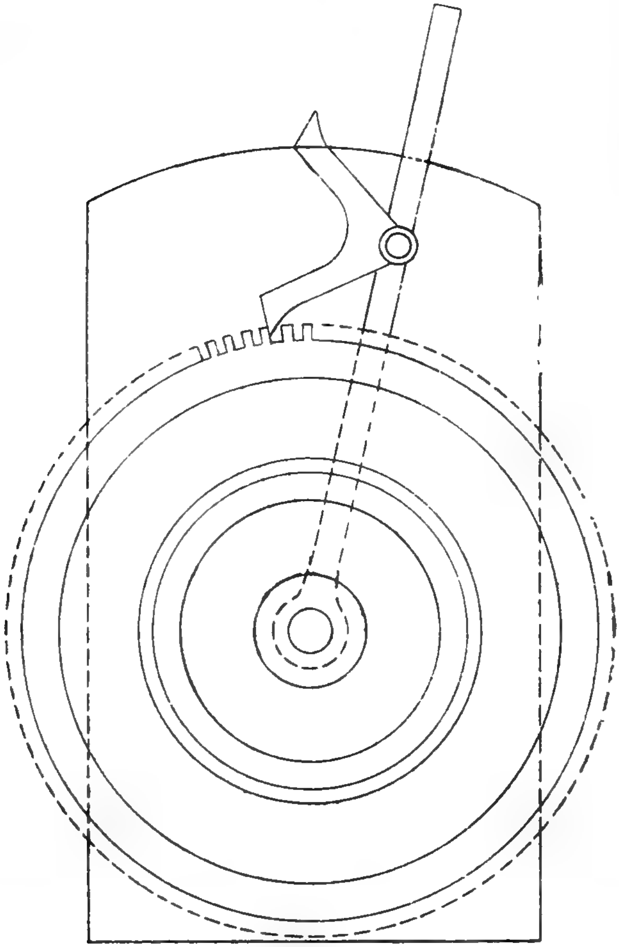


FIG. 5.



In many cases much larger circles were required than could be obtained on any ordinary board, and fig. 6 shows a side view of one of a pair of ratchet wheels which could be employed so as to do away with entirely the necessity for even one continuous axle. The ratchet wheels on either side are successively moved an equal distance by adjusting the position of two stops, one of which is shown in figs. 4 and 5. Hence for each successive position, the two pitch circles on the respective sheets of cardboard travel an equal distance, just as if they were really rolling upon each other.

FIG. 6.

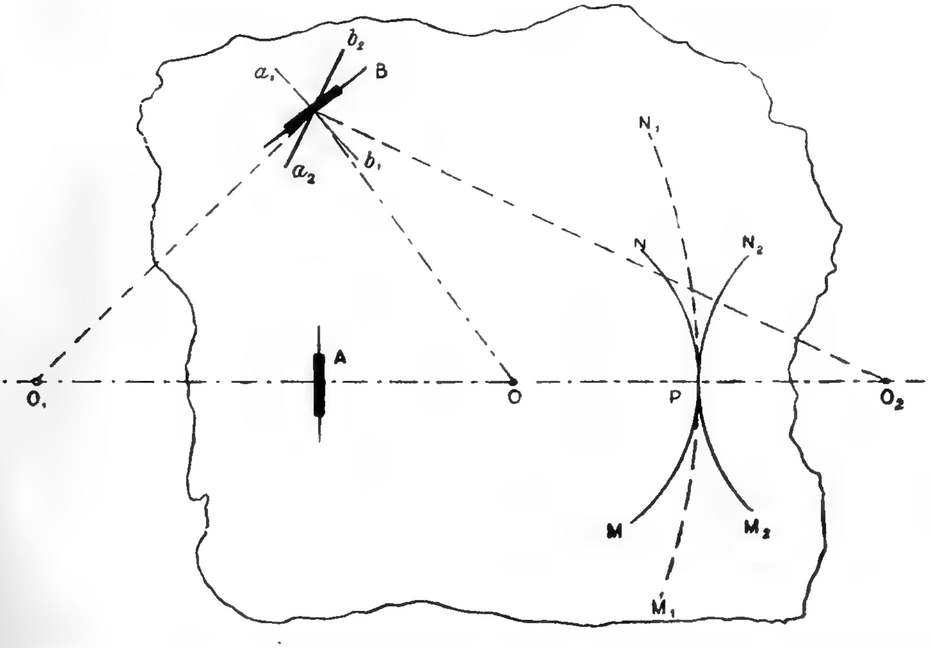


Still even with this appliance circles are often required of inconvenient size, while for drawing hypocycloidal and other curves the fixed centre of one moving surface has its position above the moving portion of the other.

An arrangement, shown in fig. 1, of sliding bars, had been adopted to overcome this difficulty, but it was obvious that the use of actual centres of rotation were often very inconvenient, since it limited the size of the rolling pitch circles, and what is believed to be an entirely new method of obtaining circles of any size was devised, which does not involve the use of an actual centre at all. This method may be briefly described as the use of two pairs of edge runners, the intersection of the axis of each pair giving the virtual centre for the rotation of the paper. It is obvious that a circle with any radius can be at once obtained by turning the direction of the axis of one pair of wheels relatively to the other, for example, when the axes are placed parallel to each other, an infinite radius is obtained, that is, the curves drawn upon the paper is a straight line. From this it will be seen that the range of the instrument is largely extended, and that instead of using an instrument of a very large size, together with trammels for setting out large wheel teeth, such teeth, even for wheels of thirty or forty feet in diameter or of a rack, can be obtained by using a small and compact instrument.

The principle of the action is explained by the diagram (fig. 7), in which is shown the upper rollers A and B of each pair of rollers through which the sheet of cardboard passes. The position of the pair of rollers A is fixed, while the frames carrying the pair represented by B can turn about a vertical axis. In the position shown in full lines, the centre of rotation is the intersection of the axis of A and B at O, and the fixed point P would therefore draw the arc M P N if the sheet of paper was moved by combination with the two pairs of wheels at A and B. If, however, the pair of rollers B are turned into the position a_1 b_1, the centre of rotation becomes O_1, and the pencil at P would describe the arc N_1 P M_1. If, on the other hand, it were turned in the position of a_2 b_2, the centre of rotation would be O_2, and the arc would now be N_2 P M_2. It will be noted that the points O_1, O_2 are outside the turning paper, and that there is nothing to prevent these centres moving away to an infinite distance in either direction by changing the position of the pair of rollers at B until their axis of rotation is parallel to that of the pair A.

FIG. 7.



The accuracy with which the circles are drawn having been thoroughly tested by constructing a simple trammel on this principle, the complete instrument shown in figs. 8 and 9 was constructed. From fig. 9 it will be seen that a graduated circle (the divisions on which were found by calculation) is used in order to set the auxiliary pair of rollers so as to give any required radius. The corresponding upper pair of rollers is afterwards turned into the required position, so that the axes of the upper and lower rollers are parallel. In the figure they are shown turned back upon a hinge in order to insert the cardboard, after which they are turned down, and a weight placed upon a projecting pin so as to insure the requisite friction when in action.

FIG. 8.

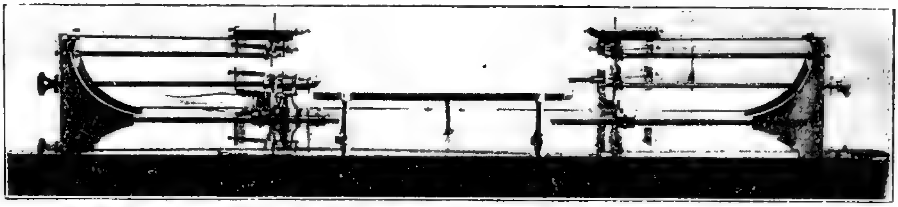
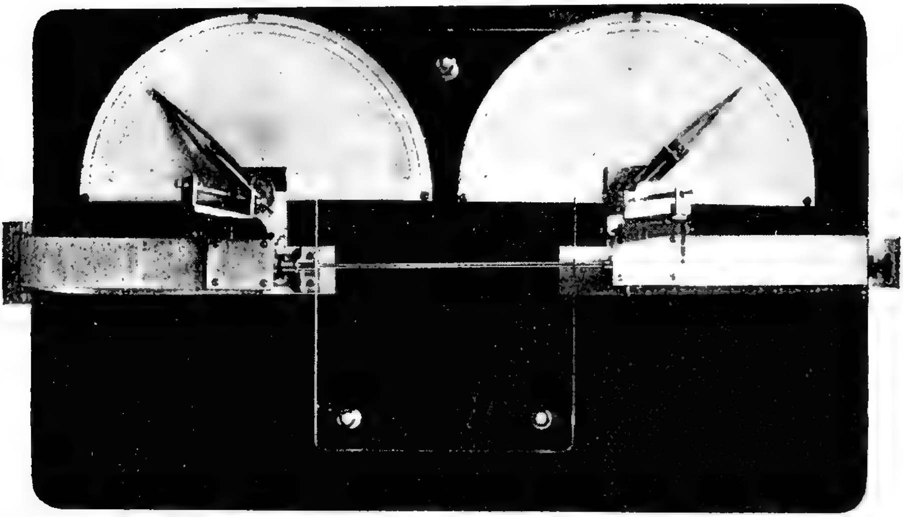


FIG. 9.

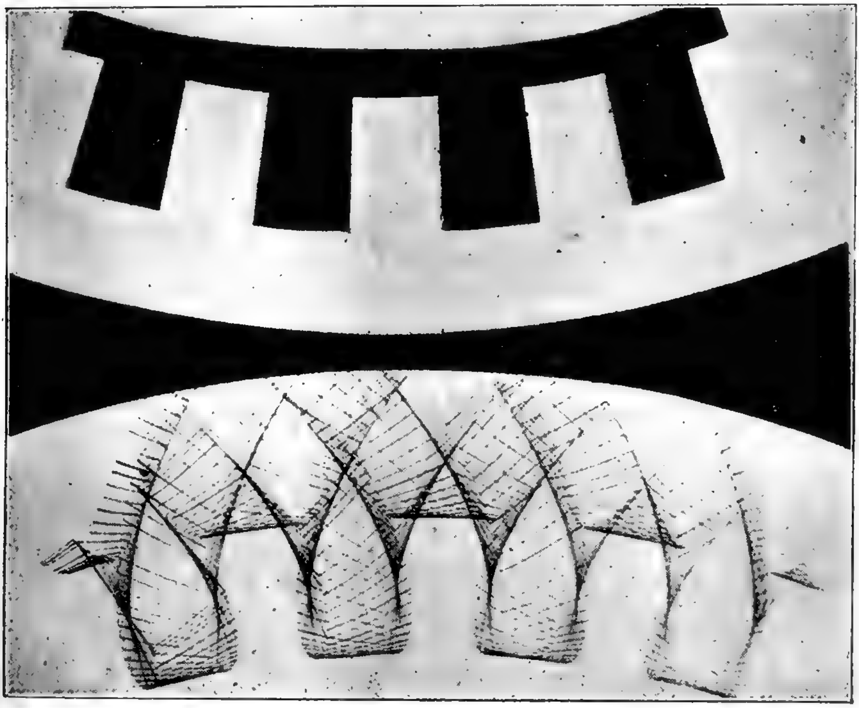


An examination of fig. 8 will show that not only can the auxiliary pair of rollers be lifted up, but that the frame carrying the main rollers can also be turned back about pivots which are shown at the end of the frame. It may also be noted that the plane surface upon which the cardboard moves can now be made of glass, since actual pivots for the centres are no longer required. This enables the two moving pieces of cardboard to slide easily, and is very much cleaner to use than a wooden or metal surface. The main spindle under the glass plate through which motion can be transmitted to both sheets of cardboard by turning the milled heads at either end has upon it a pair of bevel wheels which gear with a third bevel wheel carried upon a vertical axis. This arrangement is for the purpose of drawing various forms of cycloidal curves for setting out the teeth of wheels for which the two sheets of paper are required to revolve in opposite directions. The bevel wheels can be thrown in or out of gear, to either enable this to be done or the main spindle to be coupled up in one piece, so as to revolve in the ordinary manner.

It may also be pointed out that not only cycloidal but involute and other classes of rolling curves may be drawn by means of this instrument.

Examples of the simplest forms of applying this instrument are shown in figs. 10, 11, and 12. The upper part of the figure shows an outline selected, and the lower part the result of tracing in a number of consecutive positions the outline of the selected figure, the result being an envelope representing the profile of the curve or 'gear' which would engage with it.

FIG. 10.



In fig. 10, in which the selected form is a radial square tooth of rectangular section, it is clear that a portion of the envelope required for contact as the tooth is coming into gear is swept away or removed as the selected profile is coming out of gear; hence it would be impossible to find an envelope corresponding with the selected form which would work smoothly in practice, or avoid considerable 'back-lash.'

The next case chosen for the profile is that of the standard American screw thread. In this case the resulting envelope gives a tooth which would work quite smoothly, but the normal of the surface in contact nearly always is in a direction which would result in considerable pressure upon the bearings of the two shafts.

Fig. 12, in which an ordinary cycloidal tooth has been taken for the profile, gives, as a result, another tooth of cycloidal form, and shows that the mutual action would not only be perfectly smooth, and that there

FIG. 11.

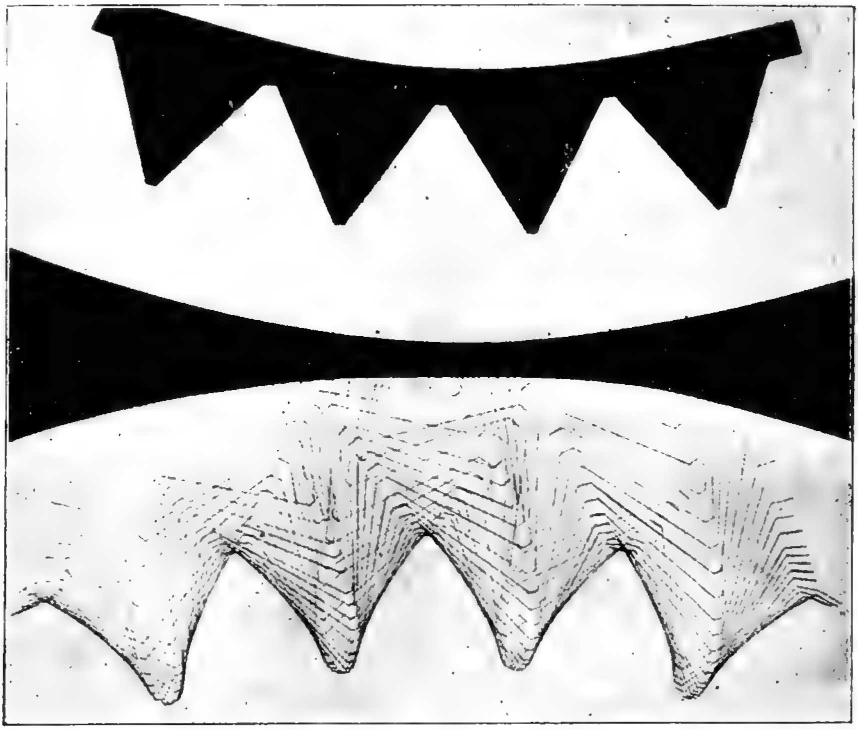
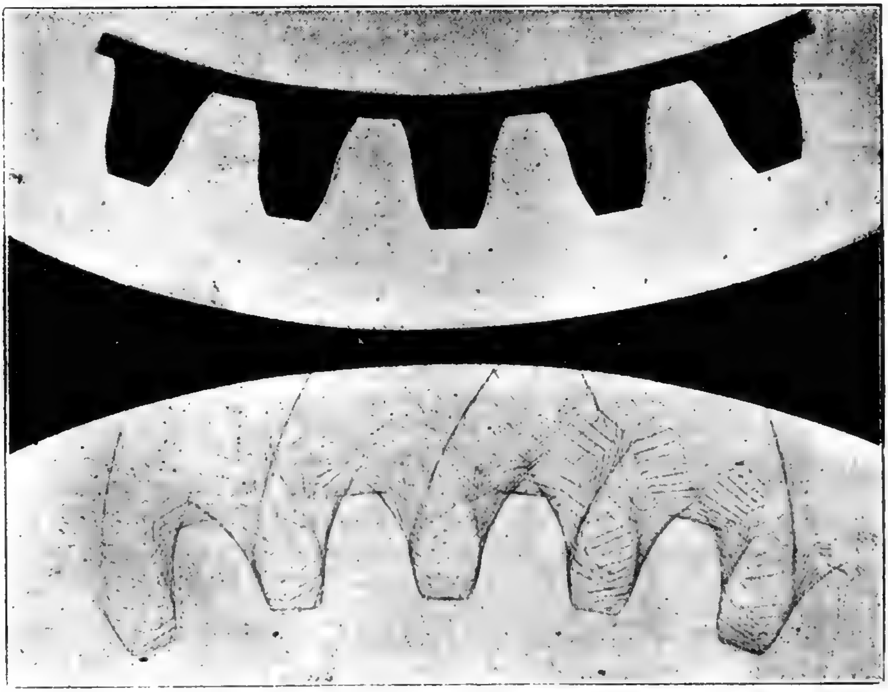


FIG. 12.



would be no 'back-lash,' but that the angle of contact is such as to enable the requisite force to be transmitted from one tooth to another under entirely satisfactory conditions.

In figs. 10, 11, and 12 there are certain clearly marked pairs of curves, which might respectively be called the curves of 'approach and recess' contact, and 'approach and recess clearance,' and it will be seen that the two halves of each curve form a cusp. If these curves afterwards cross, as in fig. 10, it may be said that the envelope will not work satisfactorily with the profile, whereas if they do not cross, as in figs. 11 and 12, the two forms will work smoothly together in contact.

By means of this instrument a large number of profile forms and envelopes have been drawn for wheel and rack teeth of various forms, also outlines for revolving pairs required to work in contact, such as Root's blowers, rotary-engines, water-meters, &c.; but the foregoing examples are sufficient to illustrate the method.

The author would conclude by acknowledging the kind assistance of his former student, Mr. E. Brown, B.Sc., Victoria University Scholar, in working out the necessary details and preparing the drawings.

Screw Gauge.—Third Report of the Committee, consisting of Mr. W. H. PREECE (*Chairman*), Lord KELVIN, Sir F. T. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Col. WATKIN, Messrs. CONRAD W. COOKE, R. E. CROMPTON, A. STROH, A. LE NEVE FOSTER, C. T. HEWITT, G. K. B. ELPHINSTONE, T. BUCKNEY, E. RIGG, C. V. BOYS, *and* W. A. PRICE (*Secretary*), *appointed to consider means by which Practical Effect can be given to the Introduction of the Screw Gauge, proposed by the Association in* 1884.

DURING the last year your Committee has been in continued communication with the Pratt and Whitney Company, Hartford, Connecticut, U.S.A., regarding the production of the gauges for the British Association screw threads referred to in their last report. Several sets of gauges, of certain numbers only, have been produced by the firm, who were not satisfied with their exactness. They have recently informed your Committee that they are taking up the matter again on new lines, and expect to produce the gauges shortly of the required accuracy.

Your Committee have been in correspondence with Professor M. Thury, of Geneva, in order to ascertain with what degree of accuracy the thread used by Swiss watch and clock makers, and systematised by him, has been produced.

An examination of a considerable number of screws supplied to the Committee by Professor Thury shows that the Swiss thread is not produced with greater accuracy than the British Association thread.

Mr. C. Vernon Boys, F.R.S., has been added te the Committee.

Your Committee asks to be reappointed, with a grant of 2*l.* 18*s.* 10*d.*, in addition to the sum of 17*l.* 1*s.* 2*d.*, the balance of the last grant drawn but unexpended.

The North-Western Tribes of Canada.—Twelfth and Final Report of the Committee, consisting of Professor E. B. TYLOR (*Chairman*), Sir CUTHBERT E. PEEK (*Secretary*), Dr. G. M. DAWSON, Mr. R. G. HALIBURTON, Mr. DAVID BOYLE, *and* Hon. G. W. ROSS, *appointed to investigate the Physical Characters, Languages, and Industrial and Social Conditions of the North-Western Tribes of the Dominion of Canada.*

THE following Report contains the results of field-work undertaken under the auspices of the Committee during the summer of 1897. The work was carried out by Messrs. Franz Boas and Livingston Farrand. A brief summary of the results of the work of the Committee has been drawn up by Dr. Boas, and forms part of this Report.

While the work of the Committee has materially advanced our knowledge of the tribes of British Columbia, the field of investigation is by no means exhausted. The languages are known only in outline. More detailed information on the physical types may clear up several points that have remained obscure, and a more detailed knowledge of the ethnology of the northern tribes seems desirable. Ethnological evidence has been collected bearing upon the history of development of the culture-area under consideration; but no archæological investigations have been carried on which would help materially in solving these problems.

For these reasons it is a matter of congratulation to know that the ethnological investigation in British Columbia will not cease with the operations inaugurated by the Committee. Ethnological and archæological work in the Province, in the adjoining States and Territories of the United States, and on the coast of Siberia is being carried on by expeditions the expense of which is borne by Mr. Morris K. Jesup, President of the American Museum of Natural History. It is hoped that these investigations may carry the work initiated by this Committee a step farther.

I. *Physical Characteristics of the Tribes of British Columbia.*
By FRANZ BOAS *and* LIVINGSTON FARRAND.

The anthropometric measurements made during the season of 1897 were carried out by both of us according to the system applied in the previous Reports of the Committee. Before entering into a discussion of the results, it is necessary to show that the measurements of the two observers are comparable. We have carried out this comparison for the head measurements in which the personal equation is liable to attain considerable value.

We give here the averages of the various measurements taken on I., StlEmqō′lEqumQ men; II., StlEmqō′lEqumQ women; III., Chilcotin men. When we call A the averages and E the mean errors, we find:—

—	Length of Head		Breadth of Head		Height of Face	
	Boas A. E.	Farrand A. E.	Boas A. E.	Farrand A. E.	Boas A. E.	Farrand A. E.
I. .	186·0 ± 0·9	187·1 ± 0·9	158·5 ± 0·8	157·9 ± 1·2	119·9 ± 1·0	121·5 ± 1·5
II. .	179·6 ± 1·4	177·9 ± 1·4	149·8 ± 0·9	151·9 ± 1·1	114·5 ± 1·4	114·5 ± 1·4
III. .	187·0 ± 1·0	186·1 ± 1·0	159·6 ± 1·2	157·9 ± 0·9	124·3 ± 1·4	124·3 ± 1·3

—	Breadth of Face		Height of Nose		Breadth of Nose	
	Boas A. E.	Farrand A. E.	Boas A. E.	Farrand A. E.	Boas A. E.	Farrand A. E.
I. .	149·0 ± 0·8	148·8 ± 0·9	52·5 ± 0·6	50·9 ± 0·8	40·6 ± 0·5	39·4 ± 0·5
II. .	138·0 ± 0·7	139·9 ± 1·2	49·1 ± 1·1	48·6 ± 0·9	35·5 ± 0·6	35·2 ± 0·6
III. .	149·1 ± 0·7	147·2 ± 1·0	53·4 ± 0·6	52·9 ± 0·6	39·9 ± 0·5	38·7 ± 0·5

The differences between these averages are throughout slight. In order to show the comparability of the measurements still more clearly we give here the values of the differences and their errors, and the average difference and its error for each measurement which have been obtained by weighting the individual differences.

Differences between Measurements taken by Boas and Farrand and their Errors.

—	Length of Head	Breadth of Head	Height of Face	Breadth of Face	Height of Nose	Breadth of Nose
I. .	+ 1·1 ± 1·3	− 0·6 ± 1·4	+ 1·6 ± 1·8	− 0·2 ± 1·1	− 1·6 ± 1·0	− 1·2 ± 0·7
II. .	− 1·7 ± 2·0	+ 2·1 ± 1·4	0·0 ± 2·0	+ 1·9 ± 1·4	− 0·5 ± 1·4	− 0·3 ± 0·8
III. .	− 0·9 ± 1·4	− 1·7 ± 1·5	0·0 ± 1·9	− 1·9 ± 1·2	− 0·5 ± 0·8	− 1·2 ± 0·7
Average .	+ 0·1 ± 0·8	− 0·1 ± 0·8	+ 0·6 ± 1·1	− 0·3 ± 0·7	− 0·8 ± 0·5	− 0·9 ± 0·4

It appears from this table that the measurements are strictly comparable, and that the personal equation may be neglected.

The tribes which were principally studied are the Northern Shuswap, the Lillooet, the Chilcotin, and the northern tribes of the coast. The Shuswap are divided into divisions in a manner similar to the divisions of the Ntlakya′pamuQ. We have collected measurements of the StlEmqō′lEqumQ, the division of the tribe living on Fraser River, north of the town of Lillooet, of the Stī′atEmQ of North Thompson River, of the Shuswap′ō′e of Kamloops, and a few of the group inhabiting Buonaparte River. We have treated the Lillooet of Fraser River, who are mixed with Shuswap, and Ntlakya′pamuQ separately from the purer groups of Seton and Anderson Lakes. Following are the tables of measurements:—

Stature of Men.

Cm.	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	Average	No. of Cases
Tribe:																																								
Haida	—	—	—	—	—	—	1	—	1	—	—	—	1	—	1	—	1	1	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	162·6	9
Nass River Indians	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2	4	2	1	—	2	2	—	2	1	3	1	—	—	—	1	—	—	—	—	—	—	—	—	167·1	22
Tsimshian	—	—	—	—	—	—	—	—	—	—	1	—	1	1	2	2	2	—	1	—	1	—	—	—	1	2	—	1	—	—	—	—	—	—	—	—	—	—	165·6	15
Bilqula	—	—	—	—	—	—	1	—	—	—	—	3	1	2	1	—	2	—	2	1	4	1	2	1	2	2	1	—	—	—	—	—	—	—	—	—	—	—	166·1	26
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	166·2	5
Awī'ky'ēnôq	—	—	1	—	—	—	—	—	—	—	1	1	—	1	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	160·0	7
Kwakiutl	—	—	—	—	—	—	1	—	—	2	2	4	3	3	2	4	3	4	2	3	1	1	4	—	1	1	—	2	—	—	—	—	—	—	—	—	—	—	164·1	43
Delta of Fraser River	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	161·8[1]	30
Spuzzum	—	2	—	—	1	—	—	—	—	1	—	—	2	1	1	2	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	159·7[2]	13
Utā'mk·t	1	1	—	—	—	—	—	1	1	—	1	—	—	1	—	1	1	—	—	1	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	161·0	12
NtlakyapamuQ'ō'e	—	—	—	1	—	—	1	1	—	—	—	1	2	—	3	1	—	2	—	1	1	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	163·1[3]	18
Nkamtcī'nEmuQ	—	—	—	1	—	—	—	—	1	—	—	—	1	1	—	—	1	1	4	2	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1	165·9	16
Harrison Lake	144 145	1	—	—	—	—	—	—	—	1	1	1	—	—	2	—	1	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	158·0	11
Lillooet (Anderson Lake)	—	—	—	—	—	—	—	—	—	1	3	—	3	—	1	—	1	1	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	162·3	12
Lillooet (Fraser River)	—	—	—	—	—	—	—	—	—	1	—	—	3	1	1	1	—	1	—	1	1	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	164·3	12
StlEmqō'lEqumQ	—	—	—	—	—	—	1	—	2	—	1	—	—	2	1	3	8	1	3	4	3	2	2	2	—	1	1	—	—	—	—	—	—	—	—	—	—	—	165·2	37
Shuswap (Kamloops)	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	—	1	1	3	—	1	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	167·9	14
Chilcotin	—	—	—	—	—	—	1	1	2	—	3	2	—	3	—	4	2	1	2	3	3	—	—	2	2	2	—	1	—	1	—	—	—	—	1	—	—	—	165·1	36

[1] Boas and Greer.

[2] 160·5 Boas and Greer, 22 cases.

[3] 162·7 Boas and Greer, 44 cases.

Stature of Women.

Cm.	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	Average	No. of Cases
Tribe:																										
Haida	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	1	—	—	—	—	—	155·2	4
Nass River Indians	—	—	—	—	—	—	—	—	1	1	1	2	—	5	2	2	2	—	2	—	—	—	—	—	154·3	18
Tsimshian	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	152·0	3
Bilqula	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	1	1	—	2	—	—	—	157·3	7
Hē'iltsuk·	1	—	—	—	—	—	1	—	—	—	—	1	1	—	—	—	1	—	—	—	—	—	—	—	150·0	5
Awī'ky'ēnôq	—	—	—	—	—	1	—	—	1	1	2	2	2	1	—	—	1	—	—	—	—	—	—	—	151·6	11
Kwakiutl	—	—	—	—	—	1	—	—	5	2	4	2	2	2	3	5	—	1	3	3	—	—	2	—	154·3	35
Spuzzum	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—	—	1	—	—	—	—	—	—	—	153·2[1]	4
Utā'mk·t	—	—	1	—	—	1	—	1	—	1	2	—	4	1	1	—	1	—	3	1	—	—	—	—	153·2	17
NtlakyapamuQ'ō'e	—	1	—	—	1	—	1	—	2	2	3	2	2	5	3	4	3	1	1	—	—	1	—	—	153·6[2]	32
Nkamtcī'nEmuQ	—	—	—	—	—	—	—	—	—	—	—	1	1	1	1	2	—	—	1	2	2	—	—	1	157·6	12
Harrison Lake	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lillooet (Anderson Lake)	—	—	—	—	—	1	1	2	2	2	1	1	—	2	1	1	—	2	1	1	—	1	1	—	152·5	20
Lillooet (Fraser River)	—	—	—	—	—	—	1	—	1	1	—	—	3	—	3	1	2	1	—	—	1	—	—	—	154·2	14
StlEmqō'lEqumQ	—	—	—	—	1	1	2	—	—	1	2	1	3	1	2	1	2	3	3	1	—	4	—	—	155·0	28
Chilcotin	—	—	—	—	—	—	—	—	—	—	1	—	1	1	3	2	1	3	—	2	—	1	—	—	156·5	15

[1] 152·7 Boas and Greer, 15 cases.

[2] 153·1 Boas and Greer, 76 cases.

Length of Head of Men.

Mm.	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	Average	No. of Cases
Tribe:																																				
Haida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	—	1	1	—	1	—	—	—	1	—	—	—	2	—	—	—	—	194·8	9
Nass River Indians	—	—	—	—	—	—	—	—	1	—	—	—	1	1	—	2	1	2	2	—	4	1	1	2	1	1	1	—	—	2	2	1	1	—	195·3	27
Tsimshian	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	2	—	2	2	1	—	—	—	1	3	—	1	—	—	—	—	—	—	193·4	15
Bilqula	—	1	—	—	—	1	1	1	—	4	—	—	—	—	2	3	1	2	1	3	2	3	—	—	—	—	—	1	—	—	—	—	—	—	188·7	26
Spuzzum	—	—	—	—	—	—	—	3	—	1	—	2	1	—	—	—	—	1	1	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	188·3	12
Utā'mk't	—	—	1	1	—	—	—	—	1	1	1	2	1	—	3	2	1	2	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	186·7	18
NtlakyapamuQ'ō e	—	—	—	—	—	1	2	2	—	2	2	1	3	3	1	2	1	2	3	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	186·8	27
Nkamtcī'nEmuQ	—	—	—	—	—	1	—	2	—	—	—	1	2	5	3	1	2	1	—	—	1	1	—	1	1	—	—	—	1	—	—	—	—	—	188·8	23
Harrison Lake	—	1	—	1	—	1	2	1	—	2	2	1	2	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	183·1	15
Lillooet (Anderson Lake) $^{170}_{1}$	$^{172}_{1}$	—	2	1	—	1	—	1	4	3	1	1	—	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	181·7	20
Lillooet (Fraser River)	—	—	—	—	—	1	1	—	2	—	—	1	—	2	1	1	2	1	3	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	188·1	17
StlEmqō'lEqumQ	—	—	1	1	1	2	—	2	2	3	5	3	3	7	1	5	2	2	3	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	186·4	48
Shuswap (Kamloops)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chilcotin	—	—	—	—	1	1	1	3	1	3	4	2	2	2	4	2	[illegible]	2	3	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	186·6	36

Length of Head of Women.

Mm.	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	Average	No. of Cases
Tribe:																																				
Haida	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	182·0	4
Nass River Indians	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	3	1	2	1	2	4	—	2	—	—	1	1	2	—	—	—	1	186·2	21
Tsimshian	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	186·3	3
Kwakiutl	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	1	3	—	—	—	1	—	—	—	—	—	186·9	7
Spuzzum		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	184·2	5
Utā'mk't	—	—	—	—	—	1	—	—	—	1	1	—	3	—	2	1	1	1	1	1	2	2	—	1	1	1	—	—	1	—	—	—	—	—	180·9	21
NtlakyapamuQ'ō'e	—	—	1	—	1	—	1	1	2	4	3	—	—	—	3	4	1	4	2	3	3	—	3	—	1	1	—	—	—	—	—	—	—	—	178·6	38
Nkamtcī'nEmuQ	—	—	—	—	—	—	—	—	1	—	1	—	—	1	3	2	2	—	—	2	—	1	1	—	—	1	—	1	—	—	—	—	—	—	180·8	16
Harrison Lake	—	—	—	1	—	—	1	1	—	—	—	2	2	1	2	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	176·0	12
Lillooet (Anderson Lake)	—	—	—	—	—	1	—	—	2	1	1	3	1	1	1	—	1	2	—	3	1	—	1	—	2	—	—	—	—	—	—	—	—	—	178·7	21
Lillooet (Fraser River)	1	—	—	—	1	—	—	—	1	1	1	—	2	—	2	1	1	4	1	1	—	1	2	—	—	1	1	—	—	—	—	—	—	—	179·2	22
StlEmqō'lEqumQ	—	—	1	—	—	1	1	1	1	1	4	2	—	—	4	—	2	3	2	3	1	1	1	1	—	—	2	—	—	—	—	—	—	—	178·7	32
Chilcotin	—	—	—	—	—	1	—	3	3	—	1	1	2	—	1	1	2	1	2	1	2	—	1	—	—	—	—	—	—	—	—	—	—	—	177·2	22

Breadth of Head of Men.

Mm.		146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	Average	Number of Cases
Tribe:																																	
Haida		—	—	—	1	—	—	—	—	—	—	—	—	1	1	1	1	—	1	—	—	—	—	—	2	—	1	—	—	—	—	163·3	9
Nass River Indians		—	—	—	—	—	1	—	—	—	—	—	4	3	2	3	2	1	2	3	1	2	2	—	1	—	—	—	—	—	—	161·2	27
Tsimshian	143 1	—	—	—	—	—	—	—	1	2	—	2	1	—	2	3	—	—	—	1	—	—	1	1	—	—	—	—	—	—	—	158·0	15
Bilqula		—	—	1	—	—	1	1	1	—	1	1	5	3	2	2	1	—	—	1	3	1	—	2	—	—	—	—	—	—	—	159·0	26
Spuzzum		—	—	—	—	—	1	—	—	1	2	1	1	1	1	—	—	—	—	1	—	—	—	2	—	—	—	1	—	—	—	159·8	12
Utā'mk·t		—	—	—	—	—	2	—	—	1	1	3	1	1	1	3	1	1	—	1	2	—	—	—	—	—	—	—	—	—	—	158·3	18
NtlakyapamuQ'ō'e		2	—	3	1	3	3	—	2	—	3	1	2	3	—	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	153·6	27
Nkamtcī'nEmuQ		—	—	1	—	3	3	1	3	—	2	2	—	4	—	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	154·8	23
Harrison Lake		—	—	—	—	—	—	—	—	1	1	—	—	—	—	2	1	1	1	1	—	1	1	1	1	—	—	2	—	—	1	164·5	15
Lillooet (Anderson Lake)	142 1	—	—	1	—	—	—	1	2	—	—	3	4	2	—	—	1	1	—	3	1	—	—	—	—	—	—	—	—	—	—	157·0	20
Lillooet (Fraser River)		—	1	—	—	1	2	—	—	1	—	1	2	2	1	—	—	2	1	1	—	—	1	—	—	—	—	—	—	1	—	157 6	17
StlEmQō'lEqumQ		—	—	2	2	—	1	—	2	1	3	2	8	4	3	4	5	2	2	2	2	2	—	1	—	—	—	—	—	—	—	158·3	48
Shuswap (Kamloops)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chilcotin		—	—	1	—	1	—	1	1	—	3	4	3	5	2	3	2	3	2	1	1	2	—	—	1	—	—	—	—	—	—	158·8	36

Breadth of Head of Women.

Mm.	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	Average	Number of Cases
Tribe:																												
Haida	—	—	—	—	—	—	—	1	1	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	151·0	4
Nass River Indians	—	—	—	—	1	1	—	1	—	1	1	2	—	1	2	2	4	2	2	—	—	—	—	1	—	—	153·6	21
Tsimshian	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	153·3	3
Kwakiutl	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	—	—	—	—	—	2	—	—	—	—	—	154·3	7
Spuzzum	—	—	—	—	—	—	—	1	—	—	—	—	1	2	1	—	—	—	—	—	—	—	—	—	—	—	151·2	5
Utā'mk·t	—	—	—	—	—	2	3	1	1	1	1	3	1	3	1	—	3	—	1	—	—	—	—	—	—	—	150·8	21
NtlakyapamuQ'ō'e	1	1	1	1	2	1	5	5	7	2	2	2	5	2	—	1	—	—	—	—	—	—	—	—	—	—	147·9	38
Nkamtcī nEmuQ	—	—	1	1	3	1	—	2	4	1	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	147·0	16
Harrison Lake	—	—	—	—	1	—	—	—	1	—	1	2	1	1	—	—	—	1	2	—	—	1	—	—	1	—	153·9	12
Lillooet (Anderson Lake)	—	—	—	—	—	—	1	3	3	1	—	1	1	1	3	1	—	4	—	—	—	1	—	—	1	—	152·7	21
Lillooet (Fraser River)	—	—	—	—	—	—	1	—	3	3	2	1	—	2	2	3	2	1	—	2	—	—	—	—	—	—	152·5	22
StlEmQō'lEqumQ	—	—	—	1	1	1	4	2	—	4	2	—	3	3	4	2	1	3	1	—	—	—	—	—	—	—	151·0	32
Chilcotin	—	—	—	—	—	1	2	—	—	3	1	—	1	2	2	2	1	3	—	—	1	1	1	1	—	—	153·8	22

Height of Face of Men.

Mm.	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	Average	No. of Cases
Tribe:																																							
Haida	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	2	1	—	—	1	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	123·3	9
Nass River Indians	—	—	—	—	1	1	1	1	—	—	—	1	—	—	4	2	—	—	4	3	—	1	2	—	—	—	—	—	1	—	—	—	—	—	—	—	—	120·5	22
Tsimshian	—	—	—	—	—	—	—	—	1	2	—	—	—	1	1	1	—	2	—	1	—	1	1	3	—	—	1	—	—	—	—	—	—	—	—	—	—	122·3	15
Bilqula	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	—	2	1	1	1	1	3	—	4	1	4	—	1	1	1	—	—	—	—	2	—	—	126·9	26
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	123·0	5
Awī'ky'ēnôq	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	1	—	1	—	—	1	—	—	1	1	—	—	—	—	—	—	127·5	7
Kwakiutl	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	2	—	1	2	2	4	4	2	3	4	3	1	3	2	3	3	—	—	—	2	1	129·2	45
Delta of Fraser River	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	126·4	5
Spuzzum	—	1	—	—	—	—	1	—	—	1	1	—	1	1	1	2	1	—	—	—	—	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	119·2	13
Utā'mk·t	—	—	—	—	—	1	—	—	—	—	—	1	2	—	—	3	2	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	121·2	12
NtlakyapamuQ'ō'e	—	—	—	1	—	1	—	—	—	—	1	1	1	3	3	1	2	1	1	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	119·0	19
Nkamtcī'nEmuQ	—	—	—	—	—	1	1	—	—	1	1	1	—	2	1	1	—	1	—	1	1	—	—	1	1	—	1	—	—	—	1	—	—	—	—	—	—	120·9	16
Harrison Lake	1	—	1	—	—	—	—	2	—	—	1	1	1	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	115·1	11
Lillooet (Anderson Lake)	—	—	—	—	—	1	—	—	—	1	2	—	—	1	1	2	2	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	119·1	12
Lillooet (Fraser River)	—	—	—	—	—	—	1	—	—	—	—	—	—	2	1	1	—	—	3	1	—	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	122·0	12
StlEmqō'lEqumQ	—	—	—	—	—	2	1	—	1	—	3	—	2	6	2	6	1	2	2	3	2	—	1	2	—	1	1	—	1	—	—	—	—	—	—	—	—	120·5	39
Shuswap (Kamloops)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	2	2	1	—	2	—	1	—	—	1	1	—	1	—	—	—	—	—	—	—	—	124·2	14
Chilcotin	—	—	—	—	1	—	—	1	—	—	1	—	1	—	1	3	4	1	4	2	2	3	1	—	2	4	2	2	—	—	—	—	1	—	—	—	—	124·3	36

Height of Face of Women.

Mm.	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	Average	No. of Cases
Tribe:																																				
Haida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	115·7	4
Nass River Indians	—	—	—	—	—	—	—	2	1	—	1	1	1	2	—	1	2	1	—	3	1	1	—	1	—	—	—	1	—	—	—	—	—	—	113·4	19
Tsimshian	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	118·0	3
Bilqula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	1	2	1	—	—	—	—	—	—	122·0	7
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	1	—	1	—	—	1	—	—	—	—	—	—	—	—	116·8	6
Awī'ky'ēnôq	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	1	1	2	1	—	2	—	1	—	—	—	—	—	1	—	—	—	—	—	115·8	11
Kwakiutl	—	—	—	—	—	—	—	—	1	—	—	—	1	1	—	1	2	1	2	2	2	2	3	1	—	4	1	—	1	1	3	2	3	138 1	121·2	35
Spuzzum	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	112·5	4
Utā'mk·t	—	—	—	—	—	—	1	—	—	2	2	1	3	—	1	—	—	—	2	—	—	3	1	1	—	—	—	—	—	—	—	—	—	—	112·6	17
NtlakyapamuQ'ō'e	1	—	—	—	—	1	—	1	1	—	4	—	3	3	3	4	3	—	—	3	—	3	1	—	2	—	—	—	—	—	—	—	—	—	112·4	33
Nkamtcī'nEmuQ	—	—	—	—	—	—	—	—	—	—	—	1	3	—	1	1	1	—	1	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	114·1	12
Harrison Lake	—	1	—	—	—	—	—	—	—	1	1	1	1	1	—	1	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	110·5	10
Lillooet (Anderson Lake)	—	—	—	1	1	—	—	—	3	—	1	2	1	2	2	1	—	1	—	—	—	—	3	—	—	—	1	—	—	—	—	—	—	—	111·3	19
Lillooet (Fraser River)	—	—	—	—	—	—	—	1	—	1	1	1	—	1	2	1	—	—	1	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	113·0	14
StlEmqō'lEqumQ	—	—	—	—	—	—	—	2	1	1	1	—	1	3	2	—	2	2	1	3	2	2	2	1	—	1	—	1	—	—	—	—	—	—	114·5	28
Chilcotin	—	—	—	—	—	—	—	—	—	—	1	1	1	—	1	1	3	—	2	2	1	—	1	—	—	1	—	—	—	—	—	—	—	1	115·8	16

Breadth of Face of Men.

Mm.	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	Average	Number of Cases
Tribe:																																	
Haida	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	1	1	2	1	1	—	1	—	—	—	—	—	—	—	—	—	152·6	9
Nass River Indians	—	—	—	—	—	1	2	—	—	—	—	1	1	2	1	1	—	—	2	2	2	2	1	2	2	—	1	1	2	—	1	155·8	27
Tsimshian	—	—	—	—	—	—	—	—	1	1	—	1	3	3	2	—	1	1	—	1	—	—	1	—	—	—	—	—	—	—	—	150·7	15
Bilqula	—	—	—	—	1	—	—	—	1	1	—	1	3	2	3	2	1	1	2	3	3	—	1	—	—	—	—	1	—	—	—	152·5	26
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	1	—	—	—	—	1	—	—	1	1	—	—	—	—	156·4	7
Awī'ky'ēnôq	—	—	—	—	—	—	—	—	—	—	2	1	—	—	—	1	1	1	1	2	—	—	—	—	—	—	—	—	—	—	—	152·0	9
Kwakiutl	—	1	1	—	1	—	—	6	—	1	8	5	1	2	5	5	6	1	—	2	3	2	1	—	1	1	—	—	—	—	—	150·2	53
Delta of Fraser River	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	1	2	1	—	—	—	—	1	159·9	7
Spuzzum	—	—	—	—	1	—	—	1	1	1	3	2	—	—	—	—	—	2	1	—	1	—	—	—	—	—	—	—	—	—	—	148·7	13
Utā'mk·t	—	—	1	—	—	—	2	—	—	1	—	4	2	2	2	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	148·7	18
NtlakyapamuQ'ō'e	1	—	2	—	—	—	1	3	3	2	4	5	2	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	146·3	26
Nkamtcī'nEmuQ	—	—	—	1	—	—	3	2	2	2	2	3	2	2	3	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	147·1	23
Harrison Lake	—	—	—	—	1	1	1	—	—	1	2	—	—	1	—	—	1	—	1	1	2	1	1	—	—	1	—	—	—	—	—	151·5	15
Lillooet (Anderson Lake)	—	—	—	1	—	—	3	3	1	2	1	3	1	1	—	—	2	—	1	—	1	—	—	—	—	—	—	—	—	—	—	147·3	20
Lillooet (Fraser River)	—	1	1	—	1	—	—	1	—	1	1	1	1	2	2	—	4	—	—	1	—	—	—	—	—	—	—	—	—	—	—	148·4	17
StlEmqō'lEqumQ	—	1	—	—	—	1	2	4	2	3	4	7	3	4	3	2	7	2	1	—	1	1	—	—	—	—	—	—	—	—	—	148·9	48
Shuswap (Kamloops)	—	—	—	1	1	—	—	1	1	—	—	1	3	1	—	2	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	148·9	14
Chilcotin	1	—	—	—	—	—	1	4	4	1	6	2	3	3	4	2	2	2	1	—	—	—	—	—	—	—	—	—	—	—	—	148·2	36

Breadth of Face of Women.

Mm.	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	Average	Number of Cases
Tribe:																																	
Haida	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	142·2	4
Nass River Indians	—	—	—	—	—	—	1	—	—	—	1	—	—	—	1	4	3	2	1	1	2	1	3	—	—	1	—	—	—	—	—	144·2	21
Tsimshian	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	143·8	3
Bilqula	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	2	1	—	1	—	—	—	—	—	—	1	—	146·6	7
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	1	—	2	—	1	—	—	1	—	—	148·9	7
Awī'ky'ēnôq	—	—	—	—	—	—	—	—	—	—	1	1	1	1	1	1	—	—	1	—	1	1	1	1	—	—	1	—	—	—	—	144·9	12
Kwakiutl	—	—	—	—	—	—	1	—	3	—	1	2	2	4	2	1	3	5	2	5	2	3	1	1	1	—	—	—	—	1	—	143·2	40
Spuzzum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	1	—	1	—	—	—	—	—	—	—	—	—	144·6	5
Utā'mk·t	—	—	—	—	—	—	—	2	1	2	3	1	1	1	3	1	1	2	—	2	1	—	—	—	—	—	—	—	—	—	—	139·9	21
NtlakyapamuQ'ō'e	1	—	—	1	—	2	4	5	3	5	2	4	1	2	2	2	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	136·7	38
Nkamtcī'nEmuQ	—	—	—	—	—	—	1	1	4	2	—	2	1	3	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	137·6	16
Harrison Lake	—	—	—	—	—	—	—	—	1	1	—	1	4	—	1	1	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	140·3	12
Lillooet (Anderson Lake)	—	—	—	—	—	—	—	2	1	1	1	3	4	—	—	3	—	1	1	1	2	—	—	—	—	—	—	—	—	—	—	140·1	20
Lillooet (Fraser River)	—	—	—	—	—	—	1	1	1	—	—	2	1	4	2	2	2	3	1	—	—	—	1	1	—	—	—	—	—	—	—	141·1	22
StlEmqō'lEqumQ	—	—	—	—	—	—	2	3	3	2	4	2	4	1	3	—	3	1	1	—	2	—	—	1	—	—	—	—	—	—	—	139·1	32
Chilcotin	—	—	—	—	—	—	1	1	1	1	—	1	4	1	1	1	2	3	1	1	1	1	—	1	—	—	—	—	—	—	—	141·3	22

Height of Nose of Men.

Mm.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	Average	Number of Cases
Tribe:																					
Haida	—	—	2	1	1	—	1	—	—	2	—	—	1	—	—	—	—	—	—	50·9	8
Nass River Indians	—	1	4	5	2	—	5	3	1	—	—	1	—	—	—	—	—	—	—	50·6	22
Tsimshian	—	1	—	—	4	1	—	—	2	1	1	2	1	1	—	—	1	—	—	54·0	15
Bilqula	—	—	—	—	—	2	1	4	—	3	2	5	2	2	2	—	2	—	2	57·3	27
Hē'iltsuk·	—	—	—	—	1	3	—	1	—	—	—	—	—	—	—	—	—	—	—	51·2	5
Awī'ky'ēnôq	—	1	—	—	—	—	—	1	1	—	3	1	—	—	—	—	—	—	—	54·1	7
Kwakiutl	—	—	2	—	—	2	5	3	3	4	4	10	7	2	2	1	—	1	—	55·7	46
Nkamtcī'nEmuQ	—	—	3	2	1	1	3	2	1	2	1	—	—	—	—	—	—	—	—	52·0	16
Lillooet (Anderson L.)	—	2	—	1	4	1	1	2	—	—	1	—	—	—	—	—	—	—	—	50·7	12
Lillooet (Fraser R.)	—	—	—	—	2	1	1	1	1	2	1	3	—	—	—	—	—	—	—	53·9	12
Kamloops	—	—	1	—	—	—	—	3	2	1	3	2	—	—	2	—	—	—	—	55·5	14
StlEmqō'lEqumQ	1	1	2	4	3	6	6	4	2	7	1	1	—	—	—	1	—	—	—	52·1	39
Chilcotin	—	1	—	3	3	4	4	3	2	9	3	4	—	—	—	—	—	—	—	53·2	36

Height of Nose of Women.

Mm.	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	Average	Number of Cases
Tribe:																										
Haida	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	1	—	—	—	—	—	—	47·2	4
Tsimshian	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	—	50·0	3
Bilqula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	1	—	1	—	1	1	53·9	7
Hē'iltsuk·	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	1	—	1	—	—	—	—	—	—	48·8	5
Awī'ky'ēnôq	—	—	—	—	—	1	—	—	—	—	1	—	1	—	3	1	1	1	1	—	1	—	—	—	49·1	11
NtlakyapamuQ'ō'e	1	—	—	—	1	—	—	1	1	2	3	4	3	1	5	5	2	2	2	—	—	—	—	—	47·3	33[1]
Lillooet (Anderson L.)	—	—	—	—	—	1	1	—	1	3	1	2	1	1	5	1	—	—	—	—	1	1	—	—	47·1	19
Lillooet (Fraser R.)	—	—	—	—	1	—	—	2	—	1	2	4	—	1	2	—	1	—	—	—	—	—	—	—	45·6	14
StlEmqō'lEqumQ	—	—	—	—	—	—	—	—	1	1	5	2	3	2	3	4	1	1	—	3	1	—	—	1	48·8	28
Chilcotin	—	—	—	—	1	1	—	—	1	1	1	1	—	—	3	1	3	1	—	1	—	1	—	—	48·1	16

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[1] In the corresponding table of the Tenth Report of the Committee (p. 16) there is a misprint. The average for the Utā'mk·t must read 47·0, number of cases 17; for the NtlakyapamuQ'ō'e 47·3 and 29.

Breadth of Nose of Men.

Mm.	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	Average	Number of Cases
Tribe:																		
Haida	—	—	—	—	—	1	3	2	1	—	1	—	—	—	1	—	40·7	9
Nass River Indians	—	—	1	1	2	3	3	1	3	4	3	—	—	1	—	—	39·8	22
Tsimshian	1	—	—	—	1	3	2	1	4	1	—	1	—	—	—	—	39·4	14
Bilqula	—	—	3	4	2	5	1	5	2	3	—	—	—	—	—	1	38·8	26
Hē'iltsuk·	—	—	—	—	—	—	—	—	1	1	2	1	—	—	—	—	42·6	5
Awī'ky'ēnôq	—	—	—	1	1	—	—	2	2	—	1	—	—	—	—	—	39·7	7
Kwakiutl	—	—	4	3	4	8	8	6	1	6	3	1	—	1	—	—	39·3	45
Nkamtcī'nEmuQ	—	—	2	4	1	4	—	2	3	—	—	—	—	—	—	—	37·8	16
Lillooet (Anderson Lake)	—	—	1	—	—	3	1	3	1	3	—	—	—	—	—	—	39·6	12
Lillooet (Fraser River)	—	1	1	—	—	4	2	1	1	1	1	—	—	—	—	—	38·8	12
Kamloops	—	—	—	—	—	2	1	3	5	1	2	—	—	—	—	—	40·6	14
StlEmqō'lEqumQ	—	—	2	—	4	3	6	6	3	9	3	3	—	—	—	—	40·2	39
Chilcotin	—	1	—	3	3	7	5	4	7	4	1	1	—	—	—	—	39·3	36

Breadth of Nose of Women.

Mm.	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Average	Number of Cases
Tribe:																
Haida	—	—	—	—	1	1	1	—	1	—	—	—	—	—	35·7	4
Tsimshian	—	—	—	—	1	—	—	—	—	1	—	—	1	—	38·3	3
Bilqula	—	—	1	2	—	1	2	—	—	1	—	—	—	—	34·8	7
Hē'iltsuk·	—	—	—	—	—	—	—	1	1	—	1	—	—	1	39·5	4
Awī'ky'ēnôq	—	1	—	1	—	6	1	1	1	—	—	—	—	—	35·0	11
NtlakyapamuQ'ō'e	—	3	3	5	5	6	5	4	2	—	1	—	—	—	34·8	33
Lillooet (Anderson Lake)	—	1	3	—	3	—	1	3	4	2	—	2	—	—	36·2	19
Lillooet (Fraser River)	—	—	1	2	3	1	5	2	—	—	—	—	—	—	34·9	14
StlEmqō'lEqumQ	1	—	2	3	4	6	2	4	3	3	—	—	—	—	35·4	28
Chilcotin	1	—	1	—	1	2	4	3	2	—	1	1	—	—	36·1	16

Length-breadth Index. Total Series.

Per cent.	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	Average	Number of Cases
Tribe :																										
Haida	—	—	—	—	2	1	3	1	2	2	2	—	1	1	1	—	1	—	—	—	—	—	—	—	82·7	17
Nass River Indians	—	—	—	3	2	4	5	14	8	4	11	9	5	8	—	2	—	—	—	—	—	—	—	—	82·9	75
Tsimshian	1	—	—	2	—	—	3	2	2	2	3	1	1	—	—	1	—	—	—	—	—	—	—	—	81·8	18
Bilqula, undeformed	—	—	—	—	1	2	2	3	3	3	1	2	6	3	5	1	2	—	—	—	—	—	—	—	84·5	34
Awī'ky'ēnôq, undeformed	—	—	—	—	—	—	—	1	—	1	1	1	—	—	—	2	—	—	—	—	—	—	—	—	85·2	6
Kwakiutl, undeformed	—	—	—	—	—	—	2	2	4	4	1	2	1	4	1	—	—	—	—	—	—	—	—	—	83·7	21
Delta of Fraser River, undeformed	—	—	—	—	—	—	2	1	—	4	5	9	5	8	3	6	3	3	2	2	1	—	—	—	86·8	54
Spuzzum	—	—	1	—	—	1	1	1	1	3	4	1	—	2	1	—	—	—	—	2	—	—	—	—	84·2	18
Utā'mk·t	—	—	—	—	1	1	1	4	1	8	6	8	9	8	1	5	2	5	1	—	1	—	—	—	85·8	62
NtlakyapamuQ'ō'e	—	—	—	3	6	4	8	5	8	10	14	11	4	6	3	4	2	1	1	—	—	—	1	—	83·5	91
Nkamtcī'nEmuQ	—	—	2	2	—	5	6	2	5	5	6	3	5	1	—	1	—	—	—	1	—	—	—	—	82·4	44
Harrison Lake	—	—	—	—	—	—	—	—	3	1	4	1	1	3	3	1	5	4	2	5	—	—	1	1	88·7	35
Lillooet (Anderson Lake)	—	—	—	—	—	2	1	3	2	4	3	2	10	5	4	3	2	4	2	2	1	1	—	—	86·6	51
Lillooet (Fraser River)	—	—	—	1	—	1	2	5	3	4	4	6	8	5	4	—	5	3	—	1	—	—	—	—	85·3	52
StlEmqō'lEqumQ	—	—	—	—	—	4	4	5	8	12	9	11	20	16	10	5	4	1	1	1	1	—	—	—	84·4	112
Stī'atEmQ	—	—	—	—	—	—	1	1	1	—	2	3	—	2	3	2	—	—	—	—	—	—	—	—	85·5	15
Buonaparte	—	—	—	—	—	—	—	—	—	1	1	3	2	—	1	2	1	—	—	—	—	—	—	—	86·4	11
Chilcotin	—	—	—	—	—	2	2	4	3	3	9	14	8	9	8	4	4	2	—	1	2	—	—	—	85·8	75

Facial Index of Men.

Per cent. . . .	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	Average	Number of Cases.
Tribe:																										
Haida . . .	—	—	1	—	2	—	—	—	1	1	—	1	1	1	1	—	—	—	—	—	—	—	—	—	80·6	9
Tsimshian . . .	—	—	2	—	1	1	—	1	2	2	1	—	2	—	2	1	—	—	—	—	—	—	—	—	80·7	15
Lillooet (Anderson L.)	—	1	—	—	1	—	—	1	2	—	4	1	1	—	1	—	—	—	—	—	—	—	—	—	80·8	12
Lillooet (Fraser R.) .	—	—	—	—	1	—	—	1	3	1	—	—	1	2	—	2	1	—	—	—	—	—	—	—	82·7	12
Shuswap (StlEmqō'lEqumQ)	1	1	—	1	1	2	1	3	7	8	4	1	2	2	1	—	1	1	—	1	—	1	—	—	81·3	39
Chilcotin . . .	1	—	—	2	—	1	—	—	3	3	1	3	3	5	6	3	2	—	1	—	1	—	—	1	83·9	36

Facial Index of Women.

Per cent. . . .	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	Average	Number of Cases
Tribe:																			
Haida . . .	—	—	—	—	—	—	1	1	1	—	1	—	—	—	—	—	—	80·7	4
Tsimshian . . .	—	—	—	—	1	—	—	—	—	1	—	—	—	1	—	—	—	81·7	3
Lillooet (Anderson L.)	2	2	2	—	1	1	—	1	3	2	1	1	1	2	—	—	—	79·5	19
Lillooet (Fraser R.) .	—	1	—	2	—	1	1	3	1	—	2	2	—	—	1	—	—	80·4	14
Shuswap (StlEmqō'lEqumQ) . . .	—	—	—	1	—	1	2	4	2	5	4	2	3	—	1	—	3	82·6	28
Chilcotin . . .	1	—	—	—	1	2	—	2	—	2	2	2	—	2	—	1	1	82·1	16

Nasal Index of Men.

Per cent.	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	Average	No. of Cases
Tribe:																																
Lillooet (Anderson Lake)	—	—	—	—	—	—	1	—	1	—	—	—	—	—	1	—	1	—	1	1	1	1	1	—	2	—	—	—	—	1	78·4	12
Lillooet (Fraser River)	1	1	—	—	—	—	—	—	2	1	—	1	—	1	1	1	—	1	—	—	—	—	—	—	1	—	1	—	—	—	72·2	12
Shuswap (StlEmqō'lEqumQ)	—	—	—	—	—	1	1	1	1	1	—	2	1	2	2	3	4	2	—	1	2	3	4	1	1	1	5	—	—	—	77·4	39
Chilcotin	—	—	—	1	—	1	—	—	4	1	2	2	3	3	5	3	1	—	2	—	2	2	1	—	2	—	1	—	—	—	74·2	36

Nasal Index of Women.

Per cent.	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	Average	No. of Cases
Tribe:																																																		
Lillooet (Anderson Lake)	—	—	—	1	—	—	—	—	1	—	—	—	—	2	—	1	—	—	—	—	—	4	2	—	1	1	—	—	—	—	1	2	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	1	78·1	19
Lillooet (Fraser River)	—	—	—	—	—	—	—	—	1	—	—	—	1	—	1	—	—	—	—	2	—	1	—	3	—	—	—	1	1	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	77·1	14
Shuswap (StlEmqō'lEqumQ)	1	—	—	—	—	—	—	1	1	1	1	—	—	—	—	4	1	1	2	3	3	2	—	3	1	—	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	72·9	28
Chilcotin	—	—	—	—	—	—	1	—	—	—	1	—	—	1	1	2	—	—	—	3	—	—	—	2	—	1	—	1	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	75·9	16

Index of Length of Arm of Men.

Per cent. . { from { to	40·5 40·9	41·0 41·4	41·5 41·9	42·0 42·4	42·5 42·9	43·0 43·4	43·5 43·9	44·0 44·4	44·5 44·9	45·0 45·4	45·5 45·9	46·0 46·4	46·5 46·9	47·0 47·4	47·5 47·9	48·0 48·4	Average	Number of Cases
Tribe :																		
Lillooet (Anderson L.)	—	—	1	—	—	1	2	1	1	2	2	2	—	—	—	—	44·7	12
Lillooet (Fraser R.) .	—	—	—	—	1	—	2	3	3	1	—	1	—	—	—	—	44·4	11
Shuswap (StlEmqō'-lEqumQ) . . .	—	1	—	1	4	3	5	8	5	5	3	2	—	—	—	—	44·1	37
Chilcotin . . .	1	—	2	—	1	3	9	2	7	4	5	—	1	—	—	1	44·4	36

Index of Length of Arm of Women.

Per cent. . { from { to	39·0 39·4	39·5 39·9	40·0 40·4	40·5 40·9	41·0 41·4	41·5 41·9	42·0 42·4	42·5 42·9	43·0 43·4	43·5 43·9	44·0 44·4	44·5 44·9	45·0 45·4	45·5 45·9	46·0 46·4	46·5 46·9	47·0 47·4	47·5 47·9	48·0 48·4	48·5 48·9	Average	Number of Cases
Tribe :																						
Lillooet (Anderson L.)	1	—	—	—	—	—	1	2	3	3	3	—	1	3	—	1	—	—	—	1	44·1	19
Lillooet (Fraser R.) .	—	—	—	—	—	2	1	—	—	3	2	2	1	3	—	—	—	—	—	—	44·1	14
Shuswap (StlEm-qō'lEqumQ) . .	—	—	—	—	1	—	—	2	2	8	3	—	5	2	3	—	—	1	—	1	44·6	28
Chilcotin . .	—	—	—	—	—	—	2		2	2	3	1	1	1	1	—	1	—	—	—	44·1	15

Index of Height sitting of Men.

Per cent. . { from { to	48·0 48·4	48·5 48·9	49·0 49·4	49·5 49·9	50·0 50·4	50·5 50·9	51·0 51·4	51·5 51·9	52·0 52·4	52·5 52·9	53·0 53·4	53·5 53·9	54·0 54·4	54·5 54·9	55·0 55·4	Average	Number of Cases
Tribe :																	
Lillooet (Anderson L.)	1	—	—	2	—	1	1	1	—	1	1	1	2	—	1	52·0	12
Lillooet (Fraser R.) .	—	—	—	—	—	1	1	—	2	2	2	1	1	1	1	52·9	12
Shuswap (StlEm-qō'lEqumQ) . .	—	—	1	1	2	3	3	2	6	5	6	2	5	—	2	52·4	38
Chilcotin . . .	—	—	1	2	—	2	2	2	6	4	5	3	2	4	—	52·5	33

Index of Height sitting of Women.

Per cent. . . { from to	49·0 49·4	49·5 49·9	50·0 50·4	50·5 50·9	51·0 51·4	51·5 51·9	52·0 52·4	52·5 52.9	53·0 53·4	53·5 53·9	54·0 54·4	54·5 54·9	55·0 55·4	Average	Number of Cases
Tribe:															
Lillooet (Anderson Lake)	1	1	—	1	7	2	—	3	2	—	1	—	1	51·8	19
Lillooet (Fraser River) .	—	—	1	1	1	2	2	2	1	2	1	—	1	52·6	14
Shuswap (StlEmqō'lEqumQ)	—	—	—	2	2	2	6	8	1	3	1	1	2	52·8	28
Chilcotin . .	—	—	1	2	1	3	—	2	2	2	—	—	1	52·4	14

Index of Finger-reach of Men.

Per cent	98	99	100	101	102	103	104	105	106	107	108	109	110	Average	Number of Cases
Tribe:															
Lillooet (Anderson Lake)	—	—	—	—	—	2	2	2	3	1	1	—	1	105·6	12
Lillooet (Fraser River) .	—	—	—	1	—	3	3	2	2	—	1	—	—	104·3	12
Shuswap (StlEmqō'lEqumQ)	2	—	2	1	3	6	9	3	5	3	1	1	1	104·1	37
Chilcotin . . .	—	—	3	—	3	3	10	5	8	1	1	—	1	104·4	35

Index of Finger-reach of Women.

Per cent.	99	100	101	102	103	104	105	106	107	108	Average	Number of Cases
Tribe:												
Lillooet (Anderson Lake)	—	2	4	1	4	3	2	—	1	2	103·3	19
Lillooet (Fraser River) .	1	1	—	2	1	4	3	2	—	—	103·5	14
Shuswap (StlEmqō'lEqumQ)	1	3	3	2	8	1	6	1	2	1	103.3	28
Chilcotin . . .	—	2	3	2	2	2	1	2	1	—	103·0	15

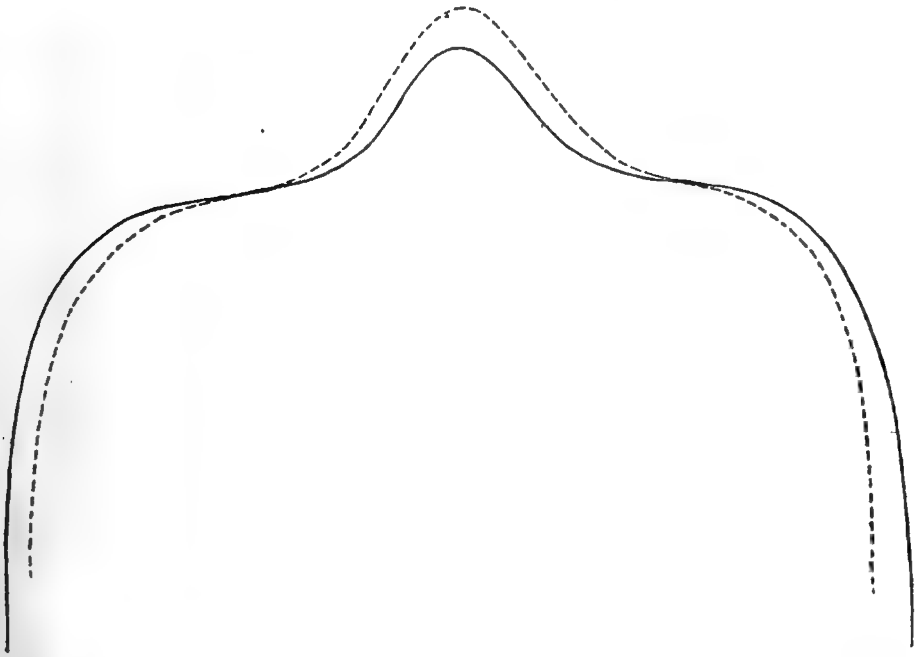
A short analysis of the material contained in the preceding tables and in previous Reports of the Committee allows us to distinguish with certainty three distinct types of man among the natives of British Columbia. These are the northern type, embracing the Haida, Nass River Indians, and Tsimshian; the Kwakiutl type, embracing the Bilqula, Hē'iltsuk·, Awī'ky'ēnôq, and the tribes of the Kwakiutl; and the Thompson River type, embracing the Lillooet and Thompson River Indians. These types may be characterised by the following measurements:—

—	Northern Type		Kwakiutl Type		Thompson River Type	
	Average	Mean Error	Average	Mean Error	Average	Mean Error
			I. Men.			
	mm.		mm.		mm.	
Stature	1675	± 7·40	1645	± 5·90	1634	± 7·90
Length of Head	194·6	± 0·80	188·7	± 1·19	186·5	± 0·55
Breadth of Head	160·6	± 0·67	159·0	± 1·00	155·9	± 0·52
Breadth of Face	153·7	± 0·85	151·4	± 0·54	147·4	± 0·41
Height of Face	121·6	± 0·87	128·0	± 0·67	120·3	± 0·71
			II. Women.			
Stature	1542	± 5·70	1537	± 5·90	1540	± 5·00
Length of Head	185·6	± 0·88	186·9	± 1·64	179·5	± 0·53
Breadth of Head	153·2	± 0·90	154·3	± 1·44	150·0	± 0·41
Breadth of Face	143·9	± 0·80	144·3	± 0·64	138·8	± 0·40
Height of Face	114·3	± 0·93	119·3	± 0·82	112·5	± 0·54

There are good indications of the existence of other types, but they cannot be distinguished with absolute certainty from the types enumerated here. It seems very probable that an examination of the Lillooet of Pemberton Meadows will establish beyond a doubt the existence of the peculiar type which in the Seventh and Tenth Reports of the Committee was named the Harrison Lake type, which is characterised by a very broad and very short head, small stature, large nose, and small face. Our measurements of the Lillooet were undertaken with a view of determining the existence of this type, but they did not extend far enough south. The characteristics of the Coast Salish of Washington and Southern British Columbia are doubtful, because the prevalent practice of deforming the head does not permit us to compare their head measurements with those of other tribes. Their faces show the same breadth as those of the other coast tribes, but their noses are much lower and flatter than those of the Kwakiutl. The Kamloops and other Shuswap tribes are closely allied to the Thompson River type, but it seems that the dimensions of their heads are a little larger, their statures a little higher. The Chilcotin resemble the Shuswap much, but their faces are flatter, their noses not so highly elevated over the face.

A study of the profiles of these types shows several important phenomena that are not elucidated in the tables of measurements. The northern type shows, on the whole, a rounded forehead; a nose which tends rather to be concave than convex, with the exception of a few individuals; short point of the nose, slight elevation of nose, long upper lip, and rather thick mouth. The Kwakiutl type shows a flat forehead, which is largely due to artificial deformation; a decidedly convex nose with short point, highly elevated over the face, and a less protruding mouth. It is very remarkable that the characteristic features of this type are so strongly marked in the female that the differences between the northern type and this type are more strongly noticed in women than in men. The Thompson River type has a very prominent, convex nose, with long point. The nose has a great elevation over the face.

We give the cross-sections of the face, laid through the tragus and lower rim of orbits for the various types. In order to make the differences clearer we have drawn a middle or composite outline for each type, which show clearly the considerable breadth of face prevailing on the coast and the flatness of the nose of the northern type.



Cross-sections of Face laid through the Tragus and the Lower Rim of the Orbit.
—— Average cross-section of the Kwakiutl, Haida, and Tsimshian.
- - - - Average cross-section of the Ntlakyapamuq and Kamloops.

The following table contains a number of repeated measurements, the first measurement having been taken in September 1894, the second in June 1897, the interval being two years and nine months. It will be seen that on the whole the measurements show a close agreement; but it appears that the error of observation for the measurements of the body, except for stature and finger-reach, is very considerable. The nasal index is also very unsatisfactory on account of the smallness of the measurements that are contained in it:—

Growth of Shuswap Children, September 1894 to June 1897.

	I. Full-blood girls							II. Full-blood boys			III. Half-blood girls			IV. Half-blood boys		
Names	Marianne	Rosalie	Julia	Augustine	Minnie	Julie	Lisette	George Alexis	Harry Duncan	Alexander Bob	Maggie Fallardeau	Aimée Manuel	Elizabeth	André Manuel	Basil Fallardeau	Alex Leonard
Age 1894	9	11	10	12	14	13	16	10	11	12	8 or 9	13	10	9	12	13
Stature	1172	1376	1308	1340	1481	1437	1449	1257	1301	1350	1213	1468	1341	1218	1390	1427
	+160	+108	+182	+115	+ 57	+113	+ 17	+108	+135	+ 76	+115	+ 54	+151	+142	+ 54	+140
Height of shoulder	933	1112	1136	1092	1212	1158	1174	1003	1045	1077	953	1183	1064	930	1105	1137
	+132	+102	+ 65	+ 78	+ 43	+ 86	+ 10	+ 97	+127	+ 73	+ 86	+ 72	+144	+163	+ 57	+133
Length of arm	509	628	684	612	677	615	641	539	557	593	522	655	591	490	590	607
	+100	+ 66	− 13	+ 60	+ 45	+ 54	+ 12	+ 48	+ 77	+ 51	+ 49	+ 27	+ 91	+117	+ 79	+ 71
Finger-reach	1166	1466	1362	1409	1580	1484	1512	1293	1296	1368	1233	1547	1408	1273	1448	1428
	+185	+ 94	+216	+133	+ 52	+ 70	+ 17	+110	+147	+ 94	+129	+ 56	+165	+143	+ 97	+175
Height sitting	650	752	717	747	811	822	798	702	716	750	664	773	727	656	736	788
	+ 70	+ 48	+ 73	+ 65	+ 19	+ 53	+ 12	+ 9	+ 39	+ 4	+ 40	+ 35	+ 70	+ 25	+ 14	+ 47
Width of shoulders	255	315	297	305	341	296	325	284	283	286	269	316	307	266	307	305
	+ 29	+ 36	+ 47	+ 42	+ 33	+ 27	+ 5	+ 19	+ 28	+ 8	+ 23	+ 15	+ 51	+ 33	+ 4	+ 42
Length of head	177	179	171	176	175	179	184	173	176	183	175	179	175	176	175	184
	+ 4	+ 1	+ 4	+ 3	+ 3	+ 4	+ 1	+ 3	+ 4	+ 2	+ 2	+ 2	+ 6	+ 4	+ 2	+ 5
Breadth of head	143	148	140	142	150	151	156	151	147	153	147	156	150	149	150	149
	+ 3	+ 0	+ 2	+ 4	+ 1	+ 2	+ 0	+ 2	+ 0	+ 2	+ 1	+ 2	+ 3	+ 3	+ 2	+ 1
Height of face	99	109	106	106	107	118	110	105	104	109	97	103	98	98	106	107
	+ 6	+ 3	+ 11	+ 7	+ 0	+ 4	+ 4	+ 7	+ 13	+ 1	+ 3	+ 5	+ 9	+ 7	+ 2	+ 8
Breadth of face	121	128	126	129	134	134	143	127	124	128	124	137	132	125	123	132
	+ 5	+ 7	+ 4	+ 7	+ 3	+ 4	+ 0	+ 4	+ 5	+ 4	+ 3	+ 3	+ 9	+ 3	+ 3	+ 4
Height of nose	41	46	44	45	46	44	43	45	48	48	41	46	39	44	45	44
	+ 3	− 1	+ 0	+ 2	+ 1	+ 7	+ 1	+ 6	+ 1	+ 0	+ 1	+ 5	+ 6	+ 1	− 4	+ 4
Breadth of nose	31	34	30	32	33	34	31	31	28	34	34	34	32	33	33	32
	+ 1	+ 1	+ 5	+ 2	+ 4	+ 1	+ 2	+ 2	+ 4	+ 1	+ 0	+ 2	+ 5	+ 1	+ 1	+ 3
Length-breadth index	80·8	82·7	81·9	80·7	85·7	84·4	84·8	87·3	83·5	83·6	84·0	87·1	85·7	84·7	85·7	81·0
	− 0·6	− 0·5	− 0·8	+ 0·8	− 0·9	− 0·8	− 0·5	− 0·4	− 1·9	+ 0·2	− 0·4	+ 0·2	− 1·2	− 0·3	+ 0·1	− 1·6
Facial index	81·8	85·2	84·1	82·2	79·9	88·1	76·9	82·7	83·9	85·2	78·2	75·2	74·2	78·4	86·2	81·1
	+ 2·3	− 2·2	+ 5·9	+ 0·9	− 1·8	+ 0·3	+ 2·7	+ 2·8	+ 6·8	− 1·9	+ 0·5	+ 1·9	+ 1·7	+ 3·6	− 0·5	+ 3·4
Nasal index	75·6	73·9	68·2	71·1	71·7	77·7	72·1	68·9	58·3	70·8	82·9	73·9	82·0	75·0	73·3	72·7
	− 1·2	+ 3·9	+11·4	+ 1·3	+ 7·0	− 8·7	+ 2·9	− 4·2	+ 7·0	+ 2·1	− 2·0	− 3·3	+ 0·2	+ 0·5	+ 9·6	+ 0·2
Index of length of arm	43·5	45·5	—	45·7	45·7	42·7	44·2	42·8	42·9	43·9	43·1	44·6	44·1	40·2	42·4	42·4
	+ 2·6	+ 1·4	—	+ 0·3	+ 1·2	+ 0·5	+ 0·2	+ 0·0	+ 1·1	+ 1·1	− 0·3	+ 0·3	+ 1·9	+ 4·4	+ 4·1	+ 0·8
Index of finger-reach	99·7	106·2	104·0	105·1	106·8	103·1	104·3	102·6	99·7	101·3	101·9	105·2	105·1	104·3	104·2	100·0
	+ 1·7	− 1·1	+ 1·9	+ 0·9	− 0·7	− 2·8	+ 0·0	+ 0·2	+ 0·8	+ 1·2	+ 0·6	+ 0·1	+ 0·3	− 0·2	+ 2·6	+ 2·3
Index of height sitting	55·6	54·5	54·7	55·7	54·8	57·1	55·0	55·7	55·1	55·6	54·9	52·6	54·3	53·8	53·0	55·1
	—	− 0·4	− 1·7	− 0·1	− 0·9	− 0·8	+ 0·2	− 3·8	− 2·7	− 2·9	− 2·0	+ 0·6	− 0·8	− 3·8	− 0·9	− 1·9
Index of width of shoulders	21·8	22·8	22·7	22·8	23·0	20·6	22·4	22·5	21·8	21·2	22·2	21·5	22·9	21·8	22·1	21·3
	—	+ 0·9	+ 0·4	+ 1·0	+ 1·3	+ 0·2	+ 0·0	− 0·4	− 0·2	− 0·6	− 0·2	+ 0·3	+ 1·1	+ 0·2	− 0·5	+ 0·8

II. *The Chilcotin.* *By* LIVINGSTON FARRAND.

The Chilcotin tribe occupies a territory lying chiefly in the valley of the Chilcotin River. They are somewhat isolated in situation, though on the east they are only separated from the Shuswap by the Fraser River. Between these two tribes, however, there is little intercourse. Toward the north their nearest neighbours are the related Tinneh tribe of Carriers or Porteurs; and while distance prevents frequent communication, they regard each other as more or less akin, and the relations are cordial. On the west a pass leads over the coast range to Bella Coola; and, as many Chilcotin make annual expeditions to the coast, they are fairly familiar with the people of that region. Toward the south the only tribe at present with whom they come in contact is the Lillooet, and with them but seldom.

Intercourse with the coast Indians, and particularly with the Bella Coola, was formerly much more frequent than now, for the reason that the early seat of the Chilcotin was considerably farther west than at present, while the Bella Coola extended higher up the river of that name into the interior. The results of this early intercourse is seen very clearly in certain of their customs, and particularly in details of their traditions. In former times and down to within about thirty years the centre of territory and population of the Chilcotin was Anahem Lake, and from here they covered a considerable extent of country, the principal points of gathering beside the one mentioned being Tatlah, Puntze, and Chizaikut Lakes. They extended as far south as Chilco Lake, and at the time of the salmon fishing were accustomed to move in large numbers down to the Chilcotin River to a point near the present Anahem Reservation, always returning to their homes as soon as the fishing was over. More recently they have been brought to the eastward, and to-day the chief centres of the tribe are four reservations—Anahem, Stone, Risky Creek, and Alexandria—the first three in the valley of the Chilcotin, and the last named, consisting of but a few families, somewhat removed from the others, on the Fraser. Besides these there are a considerable number of families leading a semi-nomadic life on the old tribal territory in the woods and mountains to the westward. These latter, considerably less influenced by civilisation than their reservation relatives, are known by the whites as Stone Chilcotin or Stonies.

Although subjected to more or less intimate intercourse with the whites for a comparatively short period, the Chilcotin have assimilated the customs and ideas of their civilised neighbours so completely that their own have largely disappeared except possibly among the families still living in the mountains, whom it was not practicable to reach.

The following notes were obtained with considerable difficulty, but the information was for the most part confirmed by the independent testimony of different individuals.

As regards the social organisation, persistent inquiry failed to disclose any traces of a clan system. The family unit was the family in the contracted sense, viz., the parents and unmarried children. Marriage was ordinarily monogamous, but many men had two wives. Recognised blood relationship was and is always an absolute bar to marriage, and at present this recognition seems to extend no further than first cousins. There seem to have been no local preferences in contracting marriages. Marriage with an individual of the same village was not regarded as more desirable than one with a person from another locality, nor *vice versâ.*

Of laws of inheritance information is rather doubtful. It was stated that in former times upon the death of a man the widow received nothing, while his relatives as far as cousins divided the estate equally. It did not descend to the children alone. To-day if a man dies the widow inherits all, apparently in trust for the children, the sons, if there be such, managing the property. No information was obtained as to the procedure in case the widow remarries. The above change of custom, if true, strongly suggests missionary influence. If an unmarried man dies leaving property it is said that his relatives as far as cousins divide the estate. A man never married his brother's widow—she was still regarded as his own sister.

Social ranks are not apparent at present, but there were formerly nobility, common people, and slaves, corresponding to a great extent to the system of the coast tribes. Wealth and the giving of feasts were the means of obtaining higher rank, and this seems to have been open to the lower class provided they had the means. Slaves were captives. From time immemorial, before the splitting up and settling upon the reservations, there seems to have been a head chief known as A′nahem, whose seat was at Anahem Lake, and whose influence extended over the whole tribe. The last great chief of that name died a few years ago, and his son is now the so-called chief of the Anahem Reservation.

Shamans, or medicine-men, are known by the term 'dī'yĭ′n,' which denotes any person of extraordinary powers who is supposed to have extra-human aid, and he becomes such by reason of some remarkable dream or experience. The deliberate candidate for such honours was accustomed to go away alone to the top of some mountain or other desolate place and there fast for several days, during which time the favourable dream might or might not come to him. The favourable dream was usually a vivid one of some animal or bird, and this became his protector and helper ever afterward. The dī'yĭ′n would then always wear some distinctive mark of his protector, such as teeth, claws, wings, feathers, &c. Aside from success in hunting and war, special powers were obtained in the cure of disease. The method of treatment was first the singing of the particular song of the dī'yĭ′n, which was his own property and used by no one else. The song was usually accompanied by dancing, but not always. Then followed the application of the hands to the body of the patient, and usually sucking through the hands placed over the diseased spot, thus drawing out the sickness. The hands were then held up in front of and above the face, and, being suddenly opened, the sickness would be sharply blown out into the air, and so expelled. Occasionally, after sucking the dī'yĭ′n would open his hands and show a grasshopper or other object, which he exhibited as the cause of the illness, and which had been thus removed. During such treatment the dī'yĭ′n usually carried a pouch containing certain charms, and, while wearing certain insignia as above stated, he did not dress in any particular robe as far as could be learned. Anyone might become dī'yĭ′n, even young boys and girls.

In former times the winter houses of the Chilcotin were the ordinary circular subterranean lodges, the excavation being about four feet in depth. There are none of these in existence to-day. The summer lodges were rectangular in shape, made of bark stretched over poles, and with only the roof and back covered, the front and two sides being thus left open. They were ordinarily built in pairs facing each other and with a common fire between. At the present time the winter houses are of logs, often very well built, and in summer tents are used, canvas for the purpose being obtained from the whites.

It was said that formerly the canoes of this tribe were made of bark stretched over wooden ribs. Both bow and stern were sharp, and were not raised above the level of the rest of the canoe. The largest of these canoes would carry about ten men. Later and at the present time the canoes are dug-outs from single logs.

Cooking was done by roasting or boiling, the latter by means of hot stones in water-tight baskets of bark or woven fibre. The hot stones were manipulated by tongs of wood.

The weapons used in war were bows and arrows and war clubs, the latter made of a stout stick about the length of the arm with a stone head fastened by leather thongs. None of these weapons are now in existence apparently. Spears with points made of the horn of the mountain sheep were used in hunting, but not in war. The arrow points were of stone. Fishing spears with detachable heads of bone were formerly very common, but are now rarely seen, and a large bone hook fastened to a rod like a gaff was also sometimes used.

In war a sort of wooden armour was worn over the chest and back as far down as the waist. This protection, in shape like a sleeveless shirt, was made of tough sticks about an inch in diameter, fastened together with leather thongs, and was sufficient to turn arrows. The head was also protected by a thick leather cap covering the entire head except the face. According to the only obtainable account of war decorations, the upper part of the face was painted black and the lower part red. Besides the leather helmet, war head-dresses were worn of the skins of birds and of the heads of animals, so arranged that the beak or mouth came forward over the forehead. The most popular skin for such head-dresses was said to have been that of the raven. Any man who was a dī'yĭ'n would wear the skin of his own protecting bird or animal.

Ear ornaments were formerly quite universally worn by both sexes, and usually in the form of small buttons of various materials attached to short strings and suspended from the lobes of the ears, which were pierced for the purpose. Older people are still found with pierced ears, but the pendants are seldom seen. Rings were also worn in the ears, but the Chilcotin say that this was a coast custom which they adopted, and was not so common as the other.

Nose ornaments of rings and straight bars inserted through the septum were also worn. One old man further described a lip ornament as a small straight bar piercing the upper lip, but this was not confirmed, and no description of labrets was obtained.

Tattooing appears to have been pretty universal, the face, chest, arms, and legs being the parts most favoured. Little information as to designs could be obtained, but it was asserted that there was no difference in the designs used by the two sexes. This is of course doubtful. The materials used in the tattooing process were bone needles and charcoal.

In general the decorative art of the Chilcotin was very slightly developed. They did not carve their weapons or utensils, and the basketry designs were and are of the simplest character.

It was said that in the old days cremation was used in the disposal of the dead, the ashes being afterwards buried. Since the arrival of the missionaries ordinary burial has been practised, the graves being protected by a low fence of logs.

The traditions of the Chilcotin are particularly interesting as showing the influence of their coast and inland neighbours, details of foreign origin being clearly traceable. Their chief tradition is of Lēndîx·tcux, a being half man and half dog, who came to the Chilcotin country from the north-west, and is their culture-hero. The story recites the adventures of Lēndîx·tcux and his three sons on their journey through the land. These adventures are chiefly with animals who before that time had been dangerous to man, but who were now overcome and made harmless. Methods of hunting and various arts were then taught to the people who previously had been wretched and ignorant. The widespread conception of the culture-hero as a trickster is especially well exemplified in this tale.

In the other traditions obtained, none of which are as full nor as important as the Lēndîx·tcux myth, but which cover a wide range of subjects, the raven is possibly the chief character, some of the stories in which he figures being identical with the raven tales of the coast, while others are apparently independent in origin. Few myths regarding natural phenomena were heard, and those which were told are of doubtful origin. The general impression was made of a not very rich independent mythology, but of surprising receptivity to foreign influences.

III. *The Social Organisation of the Haida.* *By* FRANZ BOAS.

In the Fifth Report of the Committee I briefly described the social organisation of the Haida according to information obtained from a few Indians from Skidegate. I pointed out (p. 823) that the tribe is divided into two phratries, each of which consists of a number of clans the members of which are connected by ties of consanguinity, not by an imaginary relationship through the totem. I also pointed out that the clans sometimes bear the names of the places at which their houses stand. Since this statement was made I have had opportunity to investigate the social organisation of the Tsimshian and of the Kwakiutl in greater detail. The result of these inquiries on the Tsimshians was published in the Tenth Report of the Committee, and of those on the Kwakiutl in the Report of the United States National Museum for 1895 (pp. 311–738). These investigations proved that among the southern tribes of the Pacific coast the village community was the primitive unit, and that clans originated through the coalition of village communities.

During the past summer I had an opportunity of investigating the social organisation of the Haida in somewhat greater detail, although not as thoroughly as might be desired. The information thus obtained corroborates the views expressed in the Fifth Report of the Committee, and emphasises the fact that the village community is the constituent element of the phratry.

In order to make this clear I will first of all give a list of the Haida families. The two Haida phratries are called Gyit'ina′ and K·'oā′la, and every family belongs either to the one or to the other group. Each family has a number of emblems which are commemorative of certain events in the earliest history of the family. The name of the chief of each family is hereditary. For purposes of comparison I give the list of villages recorded by Dr. G. M. Dawson in his Report on Queen Charlotte Islands (Report of Progress, Geological Survey of Canada, 1878–79, Montreal, 1880).

Kāk-oh (Dawson, *l.c.*, p. 162 B).

Not in my list ; perhaps identical with Iā'k'ō ? (see below).

Ky'iū'st'a (Dawson : Kioo-sta, p. 162 B).

Gyit'ina' : Sta'stas *or* Sañgatl lā'nas. Chief : Ē'dEnsâ (=glacier). Crests : Frog, beaver, raven, eagle. Chief's grave : Frog. An ancestor of the Sta'stas family met a giant frog in Tsiqoa'gEts. Girls when reaching maturity wear a hat that is painted green (tlt'E'ndadjang), the paint being obtained in the river NaēdE'n. Houses : 1, K·'ēgEngE nas. 2, K·oē'kyitsgyit. 3, Kun nas. 4, Nakhodā'das. 5, Skyil nās. Skyil is the mistress of copper who endows with wealth those who meet her. 6, Sk'ōlhahā'yut. 7, Naxa'was.

K'ā'was. Chief : Ētltenē'. Crests : Beaver, sg·a'ngō, eagle. The sg·a'ngō is a man who was transformed into a monster because he was living on raw fish and birds. He lives in a cave. He has long ears and wears a high hat. He carves birds as though they were large game and carries the parts home separately. When he throws them down it gives a loud noise. House : G·ōtnās.

K·a'nguatl lā'nai. Chief : Tāgyia'. Crests : Frog, eagle, beaver.

Tōgyit'inai'. Chief : Kuns. Crest : Eagle.

K·'oā'la : TōstlEngilnagai'. Chief : GwaisganEngk·'aiwa's. Crests : Ts'iliā'las (killer whale with raven wings), killer whale, bear, thunder-bird.

(The two last named belong to the village Too of Dawson, p. 170 B.)

Iā'k'ō and Dā'dens (Dawson : Tartance, p. 162 B).

K·'oā'la : Yak' lā'nas. Chief : GEsawa'k. Crests : Bear, moon, dogfish, killer whale, wolf, devilfish.

K·aok·ē'owai. Chief : G·atsō'En. Crests : Killer whale, owl, bear, woodpecker.

K·'oē'tas. Chief : HōtsElE'ng. Crests : Bear, killer whale, moon.

Gyit'ina' : Ts'ātl lā'nas. Chief : Gyit'îng·oda' and Kunkoya'n. Crests : Halibut, eagle, beaver, land otter (the last said to have been adopted recently).

S'alE'ndas. Chief : Îldzaunak·a'tlē. Crests : Frog, beaver, starfish, evening sky.

Near Dā'dens.

K·'oā'la : Tās lā'nas. Chief : Sk·anā'l. Crests : Land otter, killer whale, woodpecker, cirrus.

K·ang (Dawson : Kung, p. 163 B).

Gyit'ina' : Sak'lā'nas. Chief : Gula'c. Crests : Eagle, sculpin, beaver.

K·'oā'la : Kyā'nusla. Chief : Hā'nsgyinai. Crest : Killer whale.

WĪ′TS'A.

Gyit'ina′: Wī′ts'a gyit'inai′. Chief: Ētlgyiga.
Tōtlgya gyit'inai′. Chief: Stētlta.
Tsēts gyit'inai′. Chief: Nasgä′tl.
Dzōs hāedrai′. Chief: Gûnia′.
Crests: Eagle, humming-bird, beaver, sculpin, skate (ts'ētg·a).

These families have the same crests. They live short distances apart.

IA′AN (near Wī′ts'a. Dawson: Yān, p. 163 B).

K·'oā′la: Stl'ENGE lā′nas. Chief: NENā′k·'enas. Crests: Killer whale, hawk, bear.

Gyit'ina′: (Tsēts gyit'inai′, moved to Ia′an from Wī′ts'a a few years ago).

G·AT'AIWA′S (Dawson: Ut-te-was, p. 163 B).

K·'oā′la: Skyit'au′k·ō. Chief: Cīgai′. Crests: Killer whale, grizzly bear, black bear.

Gyit'ina′: Gyit'ī′ns. Chief: Sk·a-ina′. Crests: Eagle, beaver, sculpin.

Sg·adzē′guatl lā′nas. Chief: Skyîltk·'atsō. Crests: Eagle, beaver, sculpin.

K·'oā′la: Sg·āga′ngsilai. Crests: Killer whale, bear.

HAI′TS'AU.

K·'oā′la: G·anyakoî′nagai. Chief: Kyîlstlak·. Crests: Killer whale, bear.

K·'ĀYA′NG (Dawson: Kā-yung, p. 163 B).

K·'oā′la: Yāgun kunîlnagai′. Chief: Skyîlk·iê′s. Crests: Bear, ts'EM'â′s, killer whale.

Gyit'ina′: Saqguī′ gyit'inai′. Chief: Naok·adzō′t.
Ky'iā′ltkoangas. Chief: K'odai′.
Crests: Eagle, beaver, sculpin.

These two groups are considered branches of one family.

K·'oā′la: T'ēs kunîlnagai′. Chief: Yätl'înk'.
Dl'iā′lEN kunîlnagai′. Chief: Sēna′t.
Crests: Bear, ts'EM'â′s, killer whale.

The three groups Kunîlnagai′ in K·'aya′ng are branches of one family.

IA′GEN (about three miles north-east of Masset).

Gyit'ina′: Dl'iā′lEN k·ēowai′. Chief: Hā′yas. Crests: Eagle, raven, sculpin, frog. Said to be related to the Sta′stas.

K·'oā′la: Kun lā′nas. Chief: K·ogī′s. Crests: Bear, ts'EM'â′s, killer whale.

NAĒKU′N (Dawson: Nai-koon, p. 165 B).

Gyit'ina′: Naēku′n stastaai′. Chief: Ts'ōn. Crests the same as those of the Sta′stas, of whom they are the branch from Naēku′n.

TsiQuā′gis stastaai′. Chief: Skyilā′ō. Crests the same as those of the Sta′stas, of whom they are the branch from the river TsiQuā′gis.

K·’oā′la : qua′dōs. Chief : tl’eā′ls. Crests : Bear, killer whale, hawk, rainbow, stratus. The StI’EngE lā′nas are considered a branch of the qua′dōs, who are at present in Asegoa′n, Alaska. It is said that the qua′dōs were in the habit of catching eagles in snares. One day a man caught a hawk in his snare. Another one stole it, leaving, however, one of the hawk’s talons. This led to a quarrel, and a fight ensued, during which the family divided. Those who emigrated became the Stl’EngE lā′nas. For this reason both use the hawk and also the same personal names.

(Dawson : A-se-guang, p. 165 B.)

K·’oā′la : I was told that there was a branch of the qua′dōs at the place who moved to Skidegate.

TLK·ĀGÎLT (Skidegate).

Gyit’ina′ : Gyit’î′ns. Na yū′ans qā′edra ; Na s’ā′gas qā′edra. Chief : Sg·ēdEgî′ts. Crests : Raven, wasq, dogfish, eagle, sculpin.
Gyit’îngyits’ats. Chief : Sg·ā′nigyik·ē′do. Crests : Sculpin, eagle, wā′ts’at (a fabulous personage.)
Tsāagwī′ gyit’inai′. Chief : Winā′ts. Crests : Sculpin, eagle.

K·’oā′la : Tsāagwīsguatl’adegai′. Chief : Log·ō′t. Crests : Killer whale, gyitg·a′lya (a fabulous being), ts’Em’â′s.
Tlg·aio lā′nas. Chief ; Dō′anä′. Crests the same as the preceding family.
Tai′ōtl lā′nas. Chief : K·aäga′o. Crests : Black bear, killer whale.
K·ōg·ā′ngas. Chief : K·oē′sgutnEng’E′ndāls. Crests : Killer whale, ts’Em’â′s.

TLG·Ā′IT (Gold Harbor ; Dawson : Skai-to, p. 168 B).

K·’oā′la : Tlg·ā′itgu lā′nas. Chief : NEnkyîlstla′s. Crests : Moon, killer whale.

Gyīt′ina′ : Tlg·ā′it gyit’inai′. Chief : Ganā′i. Crests : Raven, eagle, sculpin.

K·’oā′la : Stasausk·ē′owai : Chief : Sg·anayū′En. Crest : Ts’iliā′las (killer whale with raven wings).
Skoa′tl’adas. Chief : G·ōlEntkyîngā′ns. Crests : Sea-lion, killer whale, ts’EM’â′s, thunder.

K·AI′S’un (Dawson : Kai-shun, p. 168 B).

Gyit’ina′ : K·ai′atl lā′nas. Chief : Nanā′rîskyîlQō′es. Crests : Beaver, frog, eagle.

(Dawson : Cha-atl, p. 168 B.)

K·’oā′la : tlg·ā′itgu lā′nas. (Same as above, under Tlg·ā′it.)

K·’U′NA (Skidans, Dawson : Koona, p. 169 B).

K·’oā′la : Tlk·înōtl lā′nas or K·agyalsk·ē′owai. Chief : Gudēk·a·îngā′o. Crests : Bear, moon, mountain goat, killer whale, storm cloud, cirrus, rock slide. Part of this family is called Kyīls qā'edrai. (Dawson : Tlkinool, p. 168 B.)

Gyit'ina' : K·'unak·ē'owai. Chief : Gyitk·ō'n. Crests : Dogfish, eagle, frog, monster frog, beaver.

T'ANO' (Tlō, Dawson : Tanoo, p. 169 B).

Gyit'ina' : K·'unak·ē'owai (same as in K·'u'na).
Tsēgoatl lā'nas or Laqskī'yek.

K·'oā'la : K·'adas k·ē'owai. Chief : Gyaqkutsā'n. Crests : Killer whale, wolf, ts'ᴇm'â's.

Sg·a'nguai (Nᴇnstī'ns, Dawson : Ninstance, p. 169 B).

Gyit'ina' : Gyit'ī'ns. Chief : Nᴇnstī'ns. Crests : Beaver, eagle.
K·'oā'la : Qaldā'ngasal. Chief : Ts'īni'. Crests : Bear, killer whale, ts'ᴇm'â's.

The villages on Hippah Island are not contained in my list.

A comparison of the list of families given here with that of the Skidegate families published in the Fifth Report of the Committee, p. 822, shows that the lists are fairly reliable. I give here both lists for purposes of comparison :—

Skidegate.

	(Fifth Report. Informant Johnny Swan)	Informant: Ē'densâ of Masset
Gyit'ina :	Nayū'ans qā'etqa.	Gyit'ī'ns { Na yū'ans qā'edra
	Na'sā'yas qā'etqa.	Na s'ā'gas qā'edra.
	Djāaquigi't'enai'.	Tsāagwī' gyit'inai'.
	Gyitingīts'ats.	Gyit'îngyits'ats.
K·'o'ā'la :	Naēkun k·erauā'i.	—
	Djāaqui'sk·uatl'adagā'i.	Tsāagwīsguatl'adegai'.
	Tlqaiu lā'nas.	Tlg·aio lā'nas.
	K·āstak·ērauā'i.	—
	—	Taiōtl lā'nas.
	—	K·og·ā'ngas.

It will be noticed that the Gyit'ina' families agree in both lists, while the K·'oā'la show certain discrepancies. It may be that the Naēkun-k·erauai' are the family from Asegua'n referred to above as removed to Skidegate.

It will be noticed that a great many family names are town names. Such names are Sangatl lā'nas, K·a'nguatl lā'nas, Yak' lā'nas, Tlg·aiō lā'nas, &c. Others signify 'the gyit'ina' of a certain place' ; for instance : Tō gyit'inai', Wīts'a gyit'inai', Tsāagwī gyit'inai'. Still others seem to signify 'the k·'oā'la of a certain place,' for instance : Tō stlᴇngilnagai', Ya'gun kunilnagai, Dl'iā'lᴇn kunilnagai. Another series of names signify 'the people of a certain place,' or 'those born at a certain place,' such as Dl'iā'lᴇn k·ēowai', K·'una k·eowai', and Dzōs hāedrai'.

These facts indicate that each family formed originally a local unit, so that each village would seem to have been inhabited by one family only. The present more complex village communities originated through the coalition of several families in one village, each retaining its own name and organisation. On the other hand, families divided, and are for this reason present in different villages. This is the case with the Sta′stas, whom we find under the name of Sta′stas at Ky′iū′st′a, as Naēkun stastaai′ in Naēku′n, and as TsiQuāgis stastaai′ in the same village. The Yak‘ lā′nas are partly in their old village Dā′dᴇns, partly in Tlᴇnk·oā′n (Klinquan, Alaska); the Ts′ātl lā′nas are partly in Dā′dᴇns, partly in G·augyā′n (How-aguan, Alaska). Part of the Stastas have even drifted to the Stikīnk·oan of the Tlingit. The Yak‘ lā′nas have a branch among the same tribe, where they have amalgamated with the Nanaā′ri family (Haida: Nan′a′ngi). A number of families left Queen Charlotte Islands in consequence of a quarrel, and form now the Kaigani. According to Dr. Dawson the event took place about 170 years ago (about 1730). The following families are said to have emigrated entirely: The S′alᴇ′ndas to Sakoā′n (Shakan); the K·′oē′tas to the same place; the K·aok·ē′owai to G·augyā′n (How-aguan); and the Tas lā′nas to Kasaā′n.

It is clear, therefore, that the present arrangement of families is the result of a long historical development, and that in the orginal organisation of the tribe the village community was a much more important element than it is at present.

It is also instructive to investigate the distribution of totems among these families.

I. *Gyit′ina′* (18 *distinct families*).

Eagle . . .	17	families	Starfish . . .	1	family
Beaver . . .	13	,,	Humming-bird .	1	,,
Sculpin . . .	9	,,	Skate (?) . . .	1	,,
Frog . . .	5	,,	Monster-frog . .	1	,,
Raven . . .	3	,,	Wā′ts′at . . .	1	,,
Dogfish . . .	2	,,	Wasq . . .	1	,,
Halibut . . .	1	family	Sg·a′ngo . .	1	,,
Land-otter . .	1	,,	Evening sky . .	1	,,

II. *K·′oā′la* (22 *distinct families*).

Killer whale . .	21	families	Devilfish . .	1	family
Black bear . .	14	,,	Owl . . .	1	,,
Ts′ᴇm′â′s. . .	7	,,	Land-otter . .	1	,,
Moon . . .	4	,,	Grizzly bear . .	1	,,
Woodpecker .	2	,,	Sea-lion . . .	1	,,
Tsiliā′las	2	,,	Mountain-goat .	1	,,
Thunder-bird	2	,,	Gyitg·a′lya . .	1	,,
Hawk . .	2	,,	Rainbow. . .	1	,,
Wolf . . .	2	,,	Stratus cloud . .	1	,,
Cirrus cloud . .	2	,,	Storm cloud . .	1	,,
Dogfish . . .	1	family	Rock slide . .	1	,,

This table shows a strong prevalence of two crests in each group: eagle and beaver among the Gyit′ina′, killer whale and black bear among the K·′oa′la. The sculpin and ts′ᴇm′â′s, which are next in importance, are not found among the tribes of the extreme north-western part of the islands. All the others occur only once or twice among the different families, and for this reason resemble in character the totems of the

Kwakiutl. Since the characteristic features of the traditions explaining the acquisition of these crests are also the same among the Tlingit, Haida, Tsimshian, and Kwakiutl, it is likely that they may have had the same origin. I have tried to show at another place ('Report United States National Museum for 1895,' p. 336) that among the Kwakiutl the crest is the hereditary manitou, and I am inclined to consider the isolated totems of the Haida and of the other northern tribes of similar origin. It is very doubtful if this theory holds good for the more frequent totems which evidently form the bond between the members of each group. It seems more likely that they represent the oldest totemic organisation of the tribe which may have antedated their settlement in their present locations. It is, however, worth remarking that one of the totems of secondary frequency, the ts'Em'â's, is evidently of Tsimshian origin. The name is clearly a corrupted form of ts'Em'a'ks=in the water, a fabulous monster, probably the personified snag. The four primary totems, eagle and beaver, and killer whale and bear, certainly represent the two oldest divisions of the tribe which split up in village communities that later on combined again in more complex groups.

IV. *Linguistics.* *By* FRANZ BOAS.

The Ntlakya'pamuQ.

The material for the following sketch was obtained in part directly from Mr. James Teit, in part from Indians whose statements were interpreted by Mr. Teit. The writer is, however, alone responsible for the systematic presentation of the material.

GRAMMATICAL NOTES.

THE ARTICLE.

The Ntlakya'pamuQ has an article which is similar in character to the one found in the dialects of the Coast Salish. In the Sixth Report of the Committee I briefly described the use of this article in the Bella Coola (p. 128). Its forms in other coast dialects are given in the following list:

Bilqula.	Masculine,	*ti*	Feminine,	*tsi*
Çatlō'ltq.	„	*ta*	„	*tla*
Pentlatc.	„	*ti*	„	*tla*
Nanaimo.	„	*ti*	„	*se*
Sk·qō'mic.	„	*te*	„	*tle*
Lku'ñgEn.	„	*ti*	„	*si*
Tillamook.	„	*ta*	„	*tla*

The Calispelm has the article *tlu*, which is used in the same manner. It is described by Mengarini in his 'Grammatica Linguæ Selicæ,' 1861, p. 80.

The Ntlakya'pamuQ has a number of articles.

ta is used for connecting adjectives and nouns:

stE'ptEp (1) ta (2) spEzu'zo (3), *a* (2) *black* (1) *bird* (3).
aqa (1) kEs (2) ta (3) tlōsk·a'yuQ (4) kaQ (5) puī'stEmōs (6), [*it is*] *that* (1) *bad* (2) *Indian* (4) *who* (5) *killed him* (6).

ha and *a* seem to precede nouns that are not accompanied by attributes:

ha (1) chai'tkEnEmuq (2) kaQ (3) tla'k·atEm (4), *the* (1) *Indians* (2) *who* (3) *have killed them* (4).
ha (1) Nkamtcī'nEmuQ (2) ta chai'tkEnEmuQ (3) kaQ (4) tla'k·atEm (5), *the* (1) *Nkamtcī'nEmuQ* (2) *Indians* (3) [*who* (4)] *killed them* (5).

atla'kōs (1) ha (2) kō'kpi (3) akswā'watcip (4), *when* (1) *the* (2) *chief* (3) *comes* (1), *call me* (4).
a (1) sk·'ā'um (2) pū'ists (3) ha (4) ntltcask·a'qa (5), *the* (1) *wolf* (2) *killed* (3) *the* (4) *horse* (5).
ha (1) ntltcask·ā'qa (2) pū'ists (3) a (4) sk·a'um (5), *the* (1) *horse* (2) *killed* (3) *the* (4) *wolf* (5).
a *John* pū'ists a *Sam*, *John struck Sam.*

tik seems to be more definite than *ha*, but the distinction between the two forms is by no means quite clear:

puī'zEna (1) ha (2) kō'kpi (3), *I killed* (1) *the* (2) *chief* (3).
puī'zEna (1) aqa'tik (2) kō'kpi (3), *I killed* (1) *this* (2) *chief* (3).
wa'zQEna (1) tik (2) stsuk· (3), *I showed him* (1) *the* (2) *picture* (3).
na'qEna (1) tik (2) stsuk· (3), *I gave him* (1) *the* (2) *letter* (3).
tā'we (1) aqa'tik (2) kō'kpi (3) tik (4) tlō'sk·a'yuq (5)! *what a* (1, 2) *chief* (3) *this* (4) *man* (5) [*is*]!

THE DISTRIBUTIVE.

The distributive form of the noun is formed by amplification of the stem, most frequently by reduplication. Irregular distributives of nouns are rare. Plurals of verbs are formed in the same way, but the verbal plural is frequently derived from a separate stem. The verbal plural seems to have had a distributive meaning originally, but in the intransitive verb particularly the distinction between distributive and plural is easily lost.

1. Distributives and verbal plurals formed by reduplication:

house, tcītQ	*distributive*,	tcitcī'tQ.
tree, cirā'p	”	cipcirā'p
picture, stsuk·	”	stsutsu'k.
stone, cä'EnQ	”	cEncä'EnQ.
mountain, sk·um	”	sk·umk·u'm.
ground, tEmû'Q	”	tEmtEmû'Q.
dog, sk·ā'k·qa	”	sk·ak·ā'k·qa.
cattle, stEmâ'lt	”	stEmtEmâ'lt.
calf, stEmâltitēit	”	stEmtEmâlti'tēit.
camp fire, spam	”	spEmpa'm.
coyote, snikia'p	”	snîknikia'p.
animal, spEzō'	”	spEzpEzō'.
bird, spEzu'zō	”	spEpEzu'zō.
friend, snu'koa	”	snukEnu'koa.
musk-rat, skikElā'Qoa	”	skikikEla'Qoa.
man, sk·ai'yuq	”	sk·ai'k·euq.
male of animal, sk·a'k·ayuq	”	sk·ak·a'k·ayuq.
sick, kEnu'Q	*plural*	kEnkEnu'Q.
crumpled, skō'um	”	skōumkō'um.
to walk, sQuasī't	”	sQusQuasī't.

These examples show that the laws which reduplication follows are very irregular. On the whole we may say that the prefixed *s* which is found in a very large number of Salish words is not affected by reduplication. Very often the first syllable, including the first consonant following the first vowel, is repeated with shortened vowel. But there are many exceptions to this rule. Reduplicated words may be reduplicated a second time (see musk-rat, male of an animal, in the preceding list).

2. Many nouns have the same form for the absolute and the distributive. It seems that many names of animals belong to this class:

beaver, tlk·'ō'pa (*Utā'mk·t dialect*).
beaver, snū'ya (*Nkamtcī'nEmuQ dialect*).
wolf, sk·'a'ōm ” ”
fox, EcQua'yuq ” ”
black bear, spêê'tc ” ”

deer, cmē'its	(*Nkamtcī'nEmuQ*	*dialect*).
elk, stqats	,,	,,
caribou, slEquä'qan	,,	,,
grizzly bear, cuQcu'Q	,,	,,
panther, smō'a	,,	,,
buffalo, kôisp	,,	,,
antelope, stataä'luk	,,	,,
porcupine, cutī'a	,,	,,
porcupine, skwī	,,	,,
rabbit, sk·ok·iī'ts	,,	,,
river, kowē'	,,	,,
fire, tuktī'k·	,,	,,
water, kōu	,,	,,
star, nkoku'cEn	,,	,,

3. Different stems are used for forming distributive, viz. plural and absolute forms:

	Distributive
horse, ntltcask·a'qa	sk·aqk·a'qa.
Indian, tlōsk·ai'yuq	s'ai'tkênEmuq.

	Plura
to weep, wawī'îQ	k·oê'k·t.
to stand, stē'dlîQ	tsē'iQ.
to die, zôk·	Qô'it.
to kill, pūi'stEm	tlE'k'EtEm.
to lie down, pū'it	nmê'QîQ.

DIMINUTIVES.

Diminutives are also formed by means of reduplication. It seems that the prevailing form of reduplication consists in a repetition of the first syllable as far as the first vowel, with a tendency of throwing back the accent of the word to the reduplicated syllable.

	Diminutive
deer, cmē'its	cmE'mēits.
black bear, spêê'tc	spā'paats.
friend, snu'koa	nu'nkoa.
bad, kEs	kEkEEst.
large, qzu'm	qEzu'zum.
bird, spEzu'zu	spEyu'zu.

NUMERALS.

There are three sets of numerals: simple cardinals used for counting inanimate objects; and two reduplicated series, one used for counting animals, the other for counting human beings.

	Inanimate	Animate	Personal
1,	pai'a, pê'ia	piä'a	pa pea.
2,	sê'ia	sê'sia	sisai'a.
3,	k·aatlā's, k·êak·tlā's	k·êak·tlā's k·êk·aak·tlā's	k·ak·aak·tlā's.
4,	mūs	mō'ms	mū'smust.
5,	tcī'îkst	tcī'tciEkst	tcī'tciEkst.
6,	tlā'k·amakst	tlā'k·amakst tlatlā'k·amakst	tlatlā'k·amakst.
7,	tcū'łk·a	tcū'tcłk·a tcutcū'łk·a	tcū'tcułk·a.
8,	piō'ps(t)	piō'ps(t) pipiō'ps(t)	pipiō'ps(t).
9,	tE'mEł pai'a	tE'mEł piä'a	tE'mEł pa'pea.
10,	ō'pEnakst	ō'pEnakst op'ō'pEnakst	ōp'ō'pEnakst.
11,	ō'pEnakst Eł pê'ia	ō'pEnakst Eł piä'a	op'ō'pEnakst Eł pa'pea

20,	sīl ō'pEnakst	
30,	k·âł ō'pEnakst	Same as inanimate.
40,	mūł ō'pEnakst	
50,	tcī'êks ō'pEnakst	
60,	tlā'k·umaksł ō'pEnakst	
70,	tcū'łk·ał ō'pEnakst	
80,	piōpsł ō'pEnakst	
90,	tEmEł pēł ō'pEnakst tEmeł pi ō'pEnakst	
100,	qatst pê'k·Enakst qatsł pê'k·Enakst	
200,	sä'as qatst pê'k·Enakst	
300,	k·ä'ak·łā's qatst pê'k·Enakst	
400,	mūs qatst pê'k·Enakst	

The numerals five, six, ten, one hundred, are clearly compounds of *-akst*, hand. I presume five is a compound of the stem *tca*, which is found in the numeral one in Siciatl *nEtciā'lē*, Snanaimuq *nE'ts'a*, Sk·qō'mic *ntc'ō'i*, Lku'ñgEn *nE'tsa*; so that *tcī'î·kst* would mean one hand. Nine may be translated literally 'less one.'

The same classification that is used in the cardinal numbers is used in indefinite numerals; for instance—

	Inanimate	Animate	Personal
few	kwē'niQ	kwī'kwinEQ	kwē'nkwinQ.

DISTRIBUTIVE NUMERALS.

Distributive numerals are formed from the cardinals by means of reduplication. They have the same three classes that were found in the cardinal series.

	Inanimate	Animate	Personal
1 to each	paapai'a	pēapai'a	papä'pia.
2 „	sēasai'a	asiasê'sca	siasai'a.
3 „	k·aak·aatlā's k·aatlā's	k·aak·aatlā's	k aak·aatlā's.
4 „	musEmū's	moamō'ms	musmū'smust.
5 „	tciatcī'Ekst	Same as inanimate.	
6 „	tlaatlā'k·amakst		
7 „	tcūatcū'tlk·a		
8 „	pepiō'pst		
9 „	tE'mEł pēapai'a		
10 „	ōpEō'pEnakst		

THE PRONOUN.

PERSONAL PRONOUN.

	Independent	Dependent
I	ntcā'wa	--(k)En.
thou	awē'	--(k)", Q.
he	tcinī'tl	—
we	EnEmē'mutl	—kt.
ye	pia'pst	—p *or* —mp.
they	tcînku'st	—

POSSESSIVE PRONOUN.

The possessive pronoun has a number of forms analogous to those of the Shuswap. Their use has not become clear to me. I give here the various forms and a few examples of their use.

my	n—	tlEn—	lEn—	QEn—
thy	a—	tla—	la—	Qa—
his	—s			Q—s
our	—kt,—ut			
your	—p,—mp			
their	—ēQs			

Examples: ncu'tEm, *my object.*
nskī'Qaza, *my mother.*
ntcītQ, *my house.*
aqa'a tla kamu't, *this is thy hat.*
łō'a la kamu't, *that is thy hat.*
kEnu'Q tlEn ska'qa, *my horse is sick.*
kEnu'Q nska'qa, *my horse is sick.*

The two plural forms in -*kt* and in -*ut* are not exclusive and inclusive.

ska'tsont, *our father.*
ska'tsākt, *our father.*
tci'tQut aqa', *that is our house.*

I am inclined to consider the prefixes *tl*, *l-*, and Q- which appear combined with the possessive pronoun as verbal particles. The close relation between possessive pronoun and intransitive verb becomes clear in the imperfect sense, in which the object possessed is incorporated between the verb and the pronominal suffix:

kEnuQska'qakEn, *my horse was sick = sick horse I.*
but kEnu'Q tlEn ska'qa, *my horse is sick.*
kEnuQska'qak^u, *thy horse was sick = sick horse thou.*
but kEnu'Q tla ska'qa.
or kEnu'Q a ska'qa, *thy horse is sick.*

These constructions may be compared with the inflexion of the adverb that accompanies the verb (see below).

The prefix Q- seems to indicate the relation to the indirect object of the sentence:

pīpHī'tsEn Qa kamu't, *I lost it for thee thy hat.*
pīpsta'na nkamu't, *I lost my hat.*

But I found also:

tla skā'qa pū'istQtcEms tlEn katsk, *thy horse killed for me my elder brother.*

INTRANSITIVE VERB.

The intransitive verb may be inflected by means of suffixes or by means of auxiliary verbs, which latter form various tenses.

Aorist
kEnu'QkEn, *I am sick.*
kEnu'Qk^u, *thou art sick.*
kEnu'Q, *he is sick.*
kEnu'kt
kEnkEnu'Qkt } *we are sick.*
kEnu'Qp, *ye are sick.*
kEnkEnu'Q (tcînku'st)
kEnu'Q tcînku'st } *they are sick.*

Present
(o)aqkEn kEnu'Q, *I am sick.*
(o)aqk^u kEnu'Q, *thou art sick.*
(o)aq kEnu'q, *he is sick.*
(o)aqkt (kEn)kEnu'q, *we are sick.*
(o)aqp (kEn)kEnu'q, *ye are sick.*
(o)ax kEnkEnu'q, *they are sick.*

Future I.
hwī'kEn(tca)râ'it, *I shall sleep.*
hwīk^u(tca)râ'it, *thou wilt sleep.*
&c.

Future II.
râ'itkEn hwī, *I shall sleep.*
râitk^u hwī, *thou wilt sleep.*
&c.

Imperfect
oa'qkEn tlEm tlaha'ns, *I was eating.* &c.

When the intransitive verb is accompanied by an adverb the latter takes the pronominal ending, being treated like an auxiliary verb.

tlakamē'Q(k)En skEnu'Q, *I am always sick.*
tlakamē'Q(k)a skEnu'Q, *thou art always sick.*
tlakamē'Q(k) skEnu'Qs, *he is always sick.*
tlakamē'QEkt skEnu'Q, *we are always sick.*
tlakamē'Q(k)ap skEnu'Q, *ye are always sick.*
tlakamē'Q(k) skEnkEnu'Qs, *they are always sick.*

The verb with negative is treated in the same manner:

tatā'kᴇn skᴇnu'Q, *I am not sick.* &c.

The conditional mode is characterised by the prefix *a*- and the suffix -*u*.

tcu'ktcen, *to finish eating* (=*to finish with mouth*).

atcu'ktcᴇnuᴇn, *if I finish eating.*
atcu'ktcᴇnuQ, *if thou finishest eating.*
atcu'ktcᴇnus, *if he finishes eating.*
atcu'ktcᴇnut, *if we finish eating.*
atcu'ktᴇnup, *if ye finish eating.*
atcuktcu'ktcᴇnus, *if they finish eating.*

The negative conditional present is formed in the following way:

atᴇ'mōs(ta)kᴇn skᴇnu'Q, *if I am not sick.*
atᴇ'mōs(ta)ka skᴇnu'Q, *if thou art not sick.*
atᴇ'mōs(ta)k skᴇnu'Qs, *if he is not sick.*
atᴇ'mōskakt skᴇnu'Q, *if we are not sick.*
atᴇ'moskap skᴇnu'Q, *if ye are not sick.*
atᴇ'mos(tā)ks kᴇnkᴇnu'Qs, *if they are not sick.*

The negative conditional past:

taskᴇta'kᴇn skᴇnu'Q, *if I had not been sick.*

The interrogative is formed by the suffix -ᴇn:

kᴇnu'Qkᴇnᴇn, *am I sick?*
kᴇnu'Qkoan, *art thou sick?*
kᴇnu'Qᴇn, *is he sick?*
kᴇnu'Qktᴇn, *are we sick?*
kᴇnu'Qp'ᴇn, *are ye sick?*
kᴇnkᴇnu'Qᴇn, *are they sick?*

A periphrastic interrogative is formed by the dubitative particle *ska*:

skaka skᴇnu'Q, *perhaps thou art sick.*
skaak skᴇnu'Qs, *perhaps he is sick.*
skagap skᴇnu'Q, *perhaps ye are sick.*

It will be noticed that wherever the verb appears with an adverb or a particle it has the prefix s-, which makes verbal nouns, and that the third person has the suffix -s, which corresponds to the possessive pronoun. These forms are therefore identical with possessive nominal forms.

TRANSITIVE VERB.

The transitive verb incorporates the pronominal object as follows:

to see.

Object	Subject					
	I	thou	he	we	ye	they
me	—	wī'ktcᴇmuQ	wī'ktcᴇms	—	wī'ktcᴇp	wiktē'Qsᴇtcina
thee	wī'ktcᴇn	—	wīktst	wīktst	—	wiktē'Qsᴇtst
him	wī'kᴇnᴇ	wīktQ	wīkts	wī'ktᴇm	wīktp	wiktē'Qsᴇtᴇm
us	—	?	wī'ktis	—	wī'ktîp (?)	wiktē'Qsᴇtêis
ye	wī'ktimᴇn	—	wī'ktimᴇs	wī'ktimᴇt	—	wiktē'Qsᴇtᴇmîs
them	wīktē'Qsᴇnᴇ	wīktē'QsᴇmuQ	{ wīkts { wīktē'iQsᴇtᴇm }	witē'Qsᴇtᴇm	wīktp	wiktē'Qsᴇtᴇm

Verbs which have the accent on the last syllable form the following series:

k·ôiEntcū′t, *to talk to someone.*

Object	Subject				
	I	thou	he	we	ye
me	—	k·ôiEntcE′muQ	k·ôiEntcE′ms	—	k·ôiEntcēi′p
thee	k·ôiEntcī′n	—	k·ôiEntcī′s	k·ôiEntcī′t	—
him	k·ôiEnta′na	k·ôiEnta′uQ	k·ôiEntE′s	k·ôiEntE′m	k·ôiEnta′p
us	—	k·ôiEntcē′ip	k·ôiEntē′is k·ôiEntē′it	—	k·ôiEntē′ip
ye	k·ôiEntō′imEn	—	k·ôiEntū′imas	k·ôiEntō′imet	—
them	k·ôiEntē′QsEna	k·ôiEntē′QsEmuQ	k·ôiENtE′s	k·ôiEntē′QsEtEm	k·ôiEnta′p

An analysis of these forms shows that most of them originate by composition, the pronominal object following the verb, the pronominal subject following the pronominal object. The pronominal object suffixes seem to have the following forms:

me, —tcEm
thee, —tc
him, —
us, —ti
ye, —tim (*for* —tip)
them, —tēQs

The pronominal subject suffixes have the following forms:

I, —En
thou, —Q
he, —s
we, —t
ye, —p
they, —s

But they are much more irregular than the objective suffixes.

The conditional is formed in the same manner as that of the intransitive verb by means of the prefix a- and the suffix -us:

awī′ktcEnus, *if I see thee.*
awīktipus, *if thou seest us.*
awīktē′QsEnōus, *if I see them.*

PASSIVE PARTICIPLE.

łou′m, *to stab.*	łōt, *stabbed.*
ni′kEm, *to cut.*	nikt, *cut.*

From this participle the passive is formed:

oaq łōt, *he has been stabbed.*

IMPERATIVE.

The imperative of the transitive and intransitive verbs are formed in the same manner, second person singular by -a, second person plural by -ōsa:

tlaha′nza, *eat!*	ō′pita, *eat it!*
tlaha′nzōsa, *eat ye!*	ō′pitōza, *eat ye it!*

The future serves as an exhortative:

Qwikt tlaha′ns, *let us eat!* or, *we shall eat.*

The Ntlakya′pamuQ distinguishes between the transitive verb with determined object and without object. The latter is derived from the stem of the transitive verb by the ending -EM:

aqkEn tcū′um, *I am working.*	aq tcuta′na, *I work at it.*
aqkEn pê′qEm, *I am hunting*	aq pê′qEna ksmē′its, *I am hunting deer.*
Qwē′îm, *he is looking.*	Qwē′ês, *he is looking for it.*
tl′Emô′pEm, *to chop.*	aq tl′Emô′pEna, *I chop it.*
mē′Qîma, *kick!*	mē′Qita, *kick it!*
ē′tlEm, *to sing.*	ē′tlEna, *I sing it.*
pū′istEm, *to kill (one).*	pū′istEna, *I kill it.*
qôstE′m, *to love.*	aqôstE′na, *I love it.*

The relation to the indirect object is expressed by the suffix -Q, which precedes the pronominal ending:

na'qtEm, *to give.* na'qEna, *I give it.* na'qtQEna, *I give it to him.*
k·ôiEntcū't, *to talk.* k·ôiEntcu'tEmst, *he talks about thee.* k·ôiEntcu'tEmQst, *he talks in thy behalf.*

ē'tlEm, *to sing.* aq ē'tlEna, *I sing it.* aq ē'tlEQna, *I sing it for him.* aq ē'tlEmQna, *I sing for him.*

pū'istEm, *to kill.* pū'istEna, *I kill it.* pūisQEna, *I kill it for somebody.*

Qui tsuk·hē'tcEmuQ, *write me a letter.* Qui tsuk·Qē'tcEmuQ, *write a letter for me.*
pūists sk·ā'k·qas, *he kills his own dog.* pū'istQts sk·ā'k·qas, *he kills his (another man's) dog (=he kills his dog for him).*

DERIVATIVES.

I recorded the following derivatives:

Quotative	—okō	kEnu'Q'okō, *it is said he is sick.*
Putative	—nka	kEnu'Qnka, *he may be sick.*
Dubitative	—nuk	kEnu'Qnuk, *he is sick, I think.*
Affirmative	—n	kEnu'QEn, *indeed, he is sick.* pia'pstEn, *indeed, it is ye!*
Exhortative	—matl	puitamatl, *do lie down!*
Causative	—s	pū'it, *to lie down.* pū'itsEna, *I lay it down.* nkā'iQ, *to swim.* nkā'iQsena, *I swim a horse.*
Inchoative	—wīiQ	snuyawī'îQ, *to become possessed of money.* kîstEwī'îQ } *to turn bad.* kEstuwē'EQ } iawī'îQ, *to turn good.* Qinuwī'îQ, *it begins to be a long time.*
Durative	—mîQ	kEnuQEmî'QkEn, *I am always sick.*
Frequentative:	Reduplication	skEnkEnu'Q, *one who is repeatedly sick.* k·ēak·ea'ap, *one who is repeatedly indisposed.* oaq nikEni'kEna, *I cut it repeatedly.* łołoata'na, *I stabbed him repeatedly.* qaquatsta'na, *I tie it repeatedly.*
Potential	—z'a	hai'mz'akEn, *I might do the same.* tcu'umz'akEn, *I might work, I ought to work.*
Facultative	—EnwatlEn	tlahansEnwatlEn, *to be able to eat.* rôitEnwa'tlEn, *to be able to sleep.*
Desiderative	—mamEn	tlahansma'mEnkEn, *I desire to eat.* rô'itma'mEnkEn, *I desire to sleep.*
Intensive	—ap	stlahans'a'p, *to eat much.* nmanqEma'p, *to smoke much.*
Copulative	—a-us	stlk·a'us, *together.* cînzia'us, *brothers.* snukua'us, *friends.* qamana'us, *enemies.* ktQuā'usEs, *he breaks it in two (=he halves it).*
Reciprocal	—tuaQ	qatstua'Q, *tied to each other.* puistua'Q, *to kill one another.* tla'k·tuaQ, *to kill each other.* iamintua'Q, *to have friendly feelings towards one another.* stlk·auzEmtua'Q, *to put together.*
Reflexive	—tcut	mEQEtcū't, *to kick oneself* (also *to kick without hitting anything*). wīkEntcu'tkEn, *I see myself.* nikEntcu'tkEn, *I cut myself.*

The reflexive is sometimes used as a simulative:

nikiapEntcū't, *to make oneself like a coyote=to act foolishly.*
kEnuQstcū't, *to make oneself sick, or to act like a sick person.*

PREPOSITIONS.

u, uɫ, *towards, to.*
tu, tuɫ, *from.*

Examples: uü'a, *towards here, this way.*

uɫQkᴇn uɫ tcitQ, *I go into the house.*
uɫ stkamlō'ps anê'soan, (*when*) *I went to Kamloops.*
tū'a kakā'o awī'kᴇna-us, (*when*) *I saw it from far away.*
tuQai'a, tukai'a, *from here.*
tutci'a, tuktci'a, *from there.*
tuɫo'a, tukɫo'a, *from there.*
tla'kᴇn tuɫ Nkamtcī'n, *I came from Spences Bridge.*
ktcī'Qkᴇn tuɫ Nkamtcī'n, *I departed from Spences Bridge.*
tlak tuɫ estcītQ, *I came from the house.*
tlak tua tcitQ, *I came from a house.*

CONJUNCTIONS.

pᴇɫ, *and, connecting words designating persons:*

snukua'us (1) aē'ɫ (2) a (3) SᴇQuā'pamuQ (4) pᴇɫ (5) ha (6) Psqä'qᴇnᴇm (7), *Friends together* (1) *now* (2) *the* (3) *Shuswap* (4) *and* (5) *the* (6) *Chilcotin* (7).

ᴇɫ, *and, connecting all words not designating persons:*

sqä'its ᴇɫ cāᴇnq, *wood and stone.*

SUBSTANTIVALS.

I designate by the term substantivals nominal suffixes, which are used for specifying adjectives, substantives, and verbs:

—k·ēn, *head.*	qazumk·ē'n, *big-headed.*
—us, *face.*	ihus, *pretty.*
—ane, ear.	qazuma'ne, *big ear.*
	k·oa'nētᴇm, *he has piercing pains in his ear.*
—aks, *nose.*	tcīawa'ks, *nose bleeds.*
—tcīn, *mouth, language.*	ntlakyapamuQtcī'n, *Ntlakyapamuq language.*
	tcuktcin, *to finish with mouth*, i.e., *to finish eating.*
	pēatcī'n, *one word.*
	kliQutltcī'n, *another language.*
—anz, *tooth.*	
—iapsam, *neck.*	zaqiapsa'm, *long neck.*
	nzaqiapsa'm, *long-necked.*
—āqᴇn, *upper part of arm.*	kāupā'qᴇn, *broken arm.*
	tska'qᴇn, *wing, armpit.*
	zaqa'qᴇn, *long-armed.*
—äqkᴇn, *body.*	qzumä'qkᴇn, *big body.*
	piä'qkᴇn, *one body.*
—ikᴇn, *back.*	mitcaki'kᴇn, *to sit on back.*
—akst, *hand.*	pāuta'kst, *swollen hand.*
	tcumᴇna'kstᴇn, *to point with hand.*
	kāupa'kstkᴇn, *I have broken my hand.*
—ist, *stone.*	piê'ist, *one stone.*
—uciap, *fire.*	piu'ciap, *one fire.*
—kō, —atkō, *water.*	nkui'skō, *to fall into water.*
	qazuma'tkō, *great lake.*
	nza'qkō, *long lake.*
	ntlk·a'tkō, *wide lake.*
—ūimuQ, *land.*	ksū'imuQ, *bad land.*
	ihū'imuQ, *nice land.*
	kaQū'imuQ, *dry land.*
	piū'imuQ, *one country.*

—atlQ, *house.*	qazuma'tlQ, *large house.*
	ôēpā'tlQ, *house burns down.*
—aus, *trail.*	Eniamina'us, *trail for hauling = waggon-road.*
	tcutlQuā'usEnuq, *thou pointest out the way to him.*
—äiuk·, *tree.*	ihä'iuk·, *a nice tree.*
	kunEQä'iuk·, *how many trees?*
	mitcak·ā'iuk·, *sitting on a tree.*
	ok·ona'yuk·, *rotten tree, wood.*
	k·aya'yuk·, *green wood.*
	k·'ê'qiuk·, *hard wood tree.*
	za'qiak·, *long tree.*
—tlp, *species of trees and bushes.*	s'atk·tlp, *yellow pine.*
	sk·'atlp, *fir.*
—atldzîQ, *bush.*	pea'tldzîQ, *one bush.*
	kunEqa'tldzîQ, *how many bushes?*
—zanz, *driftwood.*	
—qans, *board, plank.*	k'unEqa'ns, *how many planks?*
—alks, *clothing for upper part of body.*	smūtlatsa'lks, *woman's gown.*
—ītsa, *covering for body.*	spEk·ī'tsa, *white blanket.*
	ntltsask·aqaī'tsa, *horse skin.*
	pak·ui'tsa, *to shiver with fear.*
—autl, *canoe.*	qzuma'utl, *big canoe.*
	pia'utl, *one canoe.*
—als, *knife.*	spēia'ls, *one knife.*
	qzuma'ls, *large knife.*
—lEmuq, *sack, bottle, box.*	tlina'tlEmuq, *birch bark vessel.*
—ka, *spoon, cup, bucket, pail.*	pia'ka, *one spoon.*
—akEn, *bag, bundle.*	pia'ken, *one bag.*
—äiqEn, *rope.*	piä'iqEn, *one rope.*
—tîm, *hollow thing.*	ntsîktî'm, *empty vessel.*
—uza, *round thing.*	piu'za, *one round thing.*
	spek·ō'za, *white round thing.*
—uzEm, *group of.*	piu'zEm, *one group of things.*
—aski, *song.*	stläea'ski, *dancing song.*
—mēn, *instrument.*	tsuk·mē'n, *pencil.*
	niamē'n, *tool for hauling.*

Substantivals sometimes appear in combination:

—tcīnatlQ	*door = mouth of house.*
	nkamtcinā'tlQ, *entrance of house.*
	mitcaktcinā'tlQ, *to sit in the doorway.*

Some of the substantivals are developing into classificatory terms, such as are found in the Tsimshian:—

—aks	*nose; point of a horizontal pole.*
	mitcak·a'ks, *to sit on a point.*
—k·ēn	*head; top of a long, upright object.*
	mitcak·k·ē'n, *to sit on top of.*
—ikEn	*back; middle of long thing.*
	mitcak·i'kEn, *to sit in middle of a long thing*
—aiuk·	*tree, long thing.*
	piai'uk· tik sqēts, *one (long thing) salmon.*
	piai'uk· tik tīnQ, *one (long thing) vein.*
—a-itQ	*flat thing.*
	pia'itQ stsuk·, *one sheet of paper.*
	pia'itQ ma'nta, *one piece of canvas* (*manta*, Spanish).
—k·ēn	*head*, round thing.
	piak·ê'in tkau'za, *one (round thing) egg.*

Vocabulary of the Chilcotin Language.

The Chilcotin form a branch of the Tinneh stock. The following vocabulary is designed on the lines of the vocabularies given in the Sixth and Tenth Reports of the Committee. Since I am not familiar with the grammatical structure of the language, the vocabulary must be held subject to revision:

English	Chilcotin	English	Chilcotin
man	tînnē, ta′yañ.	*all houses*	kaunētlañ k·hō̃.
woman	tsē′k·ē.	*kettle*	nō̃sai′.
boy	kyēnl.	*bow*	atlthē′n, datsa′nk'a
my girl	êsk·ē tsē′k·ē (= female child).	*arrow*	k'a.
		axe	tshēntl.
father	ā′pa	*knife*	palâ′.
thy mother	ī′nku′l.	*jack-knife*	gyi′nalk·ī′k.
my husband	sak·a′n.	*canoe*	ts'ē.
my wife	saa′t.	*moccasins*	k·e.
my child	sᴇsk ē′i.	*pipe*	k'ā′tsai,
my elder brother	sō′nar.	*wooden pipe*	tītcᴇn k'ā′tsai.
my younger brother	sik·î′l.	*tobacco*	tsrîlyo′.
my elder sister	sä′tē.	*glove*	bāt.
my younger sister	sitē′z.	*sky*	yê′t'a.
Indian	tēntlxōtē′n.	*sun*	sha.
my people	sêtltê′s.	*moon*	a′ldzi.
my head	sᴇrtsᴇ′.	*star*	sᴇn.
my hair	sᴇrtsa′ra.	*cloud*	k'ôs
my face	sᴇnē′m.	*smoke*	tlît.
my forehead	sᴇtsēᴇku′tl.	*day*	k'antsī′n.
my ear	hētsa′ra (?).	*night*	êtl'i′.
my eye	sᴇna′ra.	*morning*	k'apᴇna′q.
my nose	sētsī′nîʜ·.	*evening*	ngaratlra′tl.
my mouth	sᴇrô′.	*noon*	sâtsana′s.
my tongue	sᴇrtsôll.	*midnight*	sōtêzni′.
my tooth	sᴇrō′.	*spring*	ᴇrotlts'ᴇ′n.
my beard	sᴇta′ra.	*summer*	dan.
my neck	sᴇk'ô′s.	*autumn*	d'ᴇnk·ī′z.[1]
my arm	sᴇka′n.	*winter*	qa′i.
my hand	sᴇla′.	*wind*	nē′nts'ᴇ.
my fingers	sᴇlats'ê′i.	*thunder*	ē′ndī̃.
thy fingers	nēlats'é′i.	*lightning*	tōu′c.
my thumb	sᴇlaitchôr.	*rain*	nagutltī̃′x·.
my first finger	sᴇlāskᴇ′t.	*snow*	nādjô′s.
my second finger	sᴇlanē′.	*fire*	k·ôn.
my third finger	sᴇlāra′.	*water*	thō.
my fourth finger	sᴇlāstᴇ′t.	*ice*	ku′dlu.
finger nail	lak'ᴇ′n.	*earth*	nᴇn.
my body	sᴇnê′s.	*sea*	ya thō.
my chest	sēdzī′y.	*river*	tsirē′nli, yik·o′.
my belly	sᴇbᴇ′t.	*lake*	pēī̃.
my breasts	sᴇts'ô′r.	*snow mountain*	tsatl.
my leg	sᴇts'ᴇ′n.	*hill*	tētlku′tl.
my foot	sᴇk·ê′.	*island*	nnu.
big toe	k·ēlaitchô′r.	*salt*	lᴇsa′l (Chinook jargon).
toe nail	k·ēlak'ᴇ′n.		
my bone	sᴇku′t.	*stone*	tshê.
my heart	sᴇtsī′y (? see chest)	*tree*	titcí′n.
my blood	sᴇtí′l.	*black pine*	tcîntī′ (?).
chief	nētc'îl'i′n.	*all trees*	titcîngā′ts'êi.
house	k·hō̃.	*fuel*	tsêz.

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[1] This 'z' is exceedingly weak, so much so that part of the breath escapes laterally, giving it a decided 'l' tinge.

English	Chilcotin	English	Chilcotin
tail	kye.	*cold*	gEzk'a'z.
dog	tlēn.	*warm*	gõzē'lgun.
black bear	sEs, tãyê's.	*I*	sī'it.
deer, buck	nēsî'ñy.	*thou*	nē'în.
fly	asts'E'z.	*he*	gū'yîñ.
mosquito	ts'îH.	*we two*	nantinī'ltē (?).
snake	tlarasE'n.	*we*	kaqonētla'n.
bird	pE (?).	*all*	kāts'ê'i.
feather	tcus.	*many*	tlaā'tla.
wing	pEt'a', pEt'sE'n.	*far*	tlaagosE't.
tail of bird	pEkye'.	*near*	întltīdyîl.
foot of bird.	pEk·ê'.	*below*	kūgyaq.
foolhen	dîH.	*to-day*	k'andzi'n.
goose	qaq.	*to-morrow*	k'āpE'n.
duck	nāt'ê'i.	*yesterday*	atlqatldã'.
loon	dāndzE'n.	*he speaks the truth*	atl'a'risEn.
teal duck	nād'atsE'l.	*yes*	ha'a.
bald-headed eagle	dā'kîH.	*no*	qā'tada'.
young eagle	shaiky·.	*nothing*	dāQ.
fish	tlū'i.	*one*	ēntli'y.
salmon	kyêrs.	*two*	nã'k·ê.
trout	dEk'a'i.	*three*	tha'i.
fish tail	pEkyilarai't.	*four*	de'i.
white	tlēyê'l.	*five*	ăskōnla'.
black	tlEt'ê's.	*six*	tlgyanthai'.
red	dîldî'l.	*seven*	gyētlqatlgyanē'lt'ê.
blue	dētltsa'.	*eight*	k'aHinē'lt'ê.
yellow, green	dEltsô'r.	*nine*	tlgyalagōntanē'lt.
large	întcā'.	*ten*	tlt'a'una.
large river	kuntcak·ô.	*twenty*	nātl'a'una.
small	ntsôdl.	*thirty*	thatlya'una.
small lake	pēngō ntsōdl.	*forty*	dẽtlyauna.
small creek	tcarēnligo ntōdl.	*one hundred*	nēlagau'nēldētl'auna.
strong	nadēnt'i'.	*to eat*	ats'iyẽ'.
old man	dagōldHîn.	*to drink*	thatsêtẽ.
young	k'ā'nēralitl (?).	*I walk*	sētrasts'a'tl.
good	tlaagō'su.	*to dance*	tsEnadai'H.
bad	pēkunidyî't.	*to sing*	tsîgdyê'n.
a bad man	denē'tla ātltsE'n.	*I want to sleep*	ntāstHē'tl.
dead	daltsha'n.	*I sleep*	satlagaitlqē'n (?).
sick	dEnēita'.	*to speak*	iāzêtld'i'ky.

In the Tenth Report of the Committee (p. 33) I have compiled the known words of the Tinneh dialect that in former times was spoken in the Nicola Valley. I have compared these words with Chilcotin and Nētcā'ut'in words, first by asking for the equivalents of the English words, then by pronouncing the Nicola Valley words. In a number of cases I obtained equivalents which showed close correspondence.

English	Nicola Valley	Chilcotin	Nētcā'ut'in
woman	tsik'hi, tsē-akai'	tsē'k·ē	ts'ē'ku
black bear	sass, sus, sas	sEs	sas
ram of mountain sheep	sisia'ni	cicia'n	sriya'n
ewe of mountain sheep	tpai	çôpai'	spai'a
mountain sheep	ti-pi	tE'pi	—
lake trout	sipai'i	sā'pai	sapai'
snake	tlosHo'	tlarasE'ñ	tlagE's
bear berry	ti'nEH	tî'niH	tEnî'H
horn	(atē)	atē'	atē
arrow	k·e	k·a	k'a
child	(qe)	k·ōi	—
take it !	ētltcot (I may give you)	ēntltcū't	yîgē'itltcut

These words agree very closely on the Nicola Valley dialect and in Chilcotin. Only three among these twelve words differ in a manner which cannot well be explained by difference of perception and transcription. They are the following:

	Nicola :	*Chilcotin* :	*Nētcā'ut'in* :
ewe of mountain sheep	tpai	çôpai'	spai'a.
snake	tlosʜo'	tlarasᴇ'ñ	tlagᴇ's.
lake trout	sipai'i	sā'pai	sapai'.

Since three words were collected from more than one individual, and by three different collectors, it seems likely that there existed an actual difference between these dialects in regard to these words.

The following words of the Nicola Valley dialect was not understood by either Chilcotin or Nētcā'ut'in when read by me. In a number of cases I obtained the equivalents of the English words in the two last-named dialects.

Nicola Valley	English	Chilcotin	Nētcā'ut'in
t-haeh	*man*	tînnē, ta'yañ	tîne'
tet'-hutz	*man*	—	—
thatc	*man*	—	—
nootl	*man*	—	—
hûlhûltu'täi	*a fish*	—	—
taki'nktcin	*a fish*	—	—
zûlke'ke	*ground-hog*	tētî'ñy	têtni'
tsho	*buck of deer*	nēsî'ny	yêsts'ētîne'
tᴇqo'ztz	*soap-berry*	nō'ruc	nawa'c
notl-ta-ha't-se	*wild currant*	tqaltsᴇ'l (?)	—
n̦otlqa'tzi			
qtlona'zi			
ta-ta-ney,'	*knife*	palâ'	alî's
tēt-ta-ā-nē'			
ta-a'-ni			
tsaē	*spoon*	k·ā'niʜ	sᴇ'nts'atl
ska-kil-ih-kane	*rush mat*	gultl'î's	hutlᴇ's
naltsi'tse	*arrow-head*	dūñtai'	nū'ntai
tlutl	*packing line*	qētlā'nt'iy	qētlā't'iy
ti-li-tsa-in	*give me the spoon!*	nnan tē k·ā'niʜ	—
n-shote	*give it to me!*	nna	te
pin-a-lē-ēl-ī-ītz	*take care!*	sōtsêlnē'tlē	wô'nli
a'we qe	*come here, child*	—	

I have omitted the numerals in the comparison, because I suspect that those recorded by Mr. Mackay (*l.c.*, p. 33) are not numerals, but various words which the informant enumerated as known to him. I think that this is the case, because many of them agree nearly or quite accurately with other words of our list. Mr. James Teit, who collected a number of words from the Indians, first called my attention to this fact. The following list shows these agreements:

Numerals	Other words
one, sa-pe	sa-pie, *trout*.
two, tun-ih	tin-ih, *bear-berry*.
three, tlohl	tlotl, *packing line* (Teit).
four, na-hla-li-a	—
five, e-na-hlē	—
six, hite-na-ke	—
seven, ne-shote	n-shote, *give it to me!*
eight, k-pae	t-pae, *ewe of mountain sheep*.
nine, sas	sass, *bear*.

These agreements and the fundamental differences between these numerals and those of all other Tinneh dialects make the series more than doubtful.

Although the apparent differences of a small vocabulary like the present have no great weight, I am inclined to think that there was a difference between the Chilcotin and the Nicola Valley dialect. The language was, however, evidently very closely related to the Chilcotin, while it differed considerably from the Carrier dialects.

V. *Summary of the Work of the Committee in British Columbia.*

By FRANZ BOAS.

At the time when the Committee instituted their investigations, the inhabitants of the Pacific coast of Canada were less known than those of any other part of the North American Continent, with the exception, perhaps, of the tribes of California. What little we knew was based on the brief descriptions of early travellers, or on indirect information obtained from investigators who had been working in the regions to the north and to the south. The only noteworthy work done in recent times was that by Dr. G. M. Dawson during his frequent geological expeditions to British Columbia. But three important problems remained to be solved; the numerous languages of the coast were still unclassified, and the number of their dialects was not definitely known; the physical characteristics of the tribes had never been investigated; it was not known if they represented one homogeneous type, or if several types were found in the Province. Finally, the study of the customs of the various tribes offered a number of difficult problems in regard to the origin and significance of several phenomena.

Material advance has been made by the efforts of the Committee in all these directions. The number of languages and dialects is now known, and it does not seem likely that additional ones will be discovered. The following languages are spoken in British Columbia:—Athapaskan or Tinneh in eight dialects; Tsimshian in three dialects; Haida in two dialects; Wakashan in two divisions, the Kwakiutl with three dialects, and the Nootka with two dialects; the Salish in four main divisions with eleven dialects, and the Kootenay. In this enumeration, dialects which may be classed as well developed and pronounced provincialisms have not been counted, but only such dialects as show distinct differences in vocabulary and grammar, so that intercommunication between the tribes speaking them is, even in the case of the most closely affiliated dialects, not easy. We count, therefore, in all, thirty dialects, which have been here classed, according to their affinities, under six linguistic stocks. Grammatical sketches of all these dialects have been obtained; but a few only are known tolerably well. These are the Kwakiutl and the Tsimshian. All the others require much fuller investigation than they have heretofore received.

While the present state of our knowledge of these languages does not permit us to assume that the number of stocks to which they belong is smaller than the number given above, we may call attention at this place to the morphological relations of some of these languages, which suggest the desirability of further inquiries into their early history.

Haida and Tlingit—which latter is spoken in southern Alaska—have a number of morphological traits in common. While all the other languages of the North Pacific coast use reduplication for grammatical purposes, no trace of reduplication is found in these two languages. There is no gender, and no well-defined form for a plural or distributive. Compound nouns are very numerous, the composition being effected by juxtaposition. Words of two, three, and more components, which do not modify each other, occur. Local adverbs, which always retain their independent forms, frequently enter into compound words of this kind. In both languages there are four forms of the personal pronoun. In the independent pronoun, the selective and the ordinary forms may be distinguished. The pronoun of the transitive verb differs from that of intransitive verbs, the latter being identical with the objective form of the former. In this respect there is a close analogy between the Haida and Tlingit, and the Siouan languages.

The Tsimshian presents an entirely different type of language. We find a plural based largely on reduplication. The pronouns are suffixed to the verb. Words are formed almost exclusively by means of prefixes. The system of numerals is very complex, as there are different sets of numerals for various classes of objects.

The southern group of languages—the Kwakiutl, Salish, and Chemakum (which last is spoken in the northern part of the State of Washington)—have a series of very peculiar traits in common. Most prominent among these is the occurrence of what Trumbull has called 'substantivals,' which play so important a part in the Algonkin languages. Such are, primarily, parts of the body; furthermore, designations of localities, of fire, water, road, blanket, domesticated animals (*i.e.*, in olden times, the dog), and many others. These substantivals do not occur in any other northern language, and must be considered one of the most important characteristics of the languages in question. All these languages use reduplication and diæresis for forming collective forms and plurals of verbs. The demonstrative pronoun is used very extensively, and serves for distinguishing locations of object or action according to the three forms of the personal pronoun; namely, such as are located near the first, second, or third person. Besides these, a great many locative suffixes are used. Whenever an adverb accompanies the verb, the former is inflected, while the verb remains unchanged. When a transitive verb is accompanied by an adverb, the latter always takes the suffix of the pronominal subject, while the verb takes that of the pronominal object.

The Kootenay presents still another type of language. It incorporates the object in the same way as the Mexican does, the noun itself being embodied in the verb. It has very few substantivals, if any, but forms compounds by verbal composition, like the Tinneh (Athapascan) and Siouan. While in the preceding class we find, for instance, compounds expressing states of the hand, of water, fire, &c., we find here compounds expressing actions done with the hand, the foot, or other instrumentalities; and in the water, the fire, or in other localities. It seems that there is no reduplication.

It is worth remarking that these types of language are characterised by a few very general features that they have in common, and that distinguish them from the other groups that are found in contiguous areas. The Haida and Tsimshian are spoken in the extreme north; the Kwakiutl, Salish, Chemakum, in the whole southern portion of the Province, and they adjoin the Algonkin, with whom they have a few peculiarities in common. The Kootenay is not far separated from the Shoshonean languages, which resemble it in several particulars. We may therefore well say that the languages of the North Pacific coast belong to several morphological groups, each of which occupies a continuous area.

The investigation of the physical characteristics of the Indians of British Columbia has resulted in establishing the fact that the people are by no means homogeneous. As compared to the Indians east of the Rocky Mountains and farther south, they have in common a lighter complexion and lighter hair; but the shapes of their heads and faces differ considerably. Three types may easily be distinguished—the northern type, represented by the Haida, the Indians of Nass River, and the Tsimshian; the Kwakiutl type; and the Thompson River type.

These types may be characterised by the following measurements:—

—	Northern Type		Kwakiutl Type		Thompson River Type	
	Average	Mean Error	Average	Mean Error	Average	Mean Error
			I. *Men.*			
	mm.		mm.		mm.	
Stature	1675	± 7·40	1645	± 5·90	1634	± 7·90
Length of head . .	194·6	± 0·80	188·7	± 1·19	186·5	± 0·55
Breadth of head . .	160·6	± 0·67	159·0	± 1·00	155·9	± 0·52
Breadth of face . .	153·7	± 0·85	151·4	± 0·54	147·4	± 0·41
Height of face . .	121·6	± 0·87	128·0	± 0·67	120·3	± 0·72
			II. *Women.*			
Stature	1542	± 5·70	1537	± 5·90	1540	± 5·00
Length of head . .	185·6	± 0·88	186·9	± 1·64	179·5	± 0·53
Breadth of head . .	153·2	± 0·90	154·3	± 1·44	150·0	± 0·41
Breadth of face . .	143·9	± 0·80	144·3	± 0·64	138·8	± 0·40
Height of face . .	114·3	± 0·93	119·3	± 0·82	112·5	± 0·54

They may be described as follows: All these types are of medium stature, and their arms are relatively long, their bodies short. Among the northern type we find a very large head. The transversal diameter is very great. The same may be said of the face, which has an enormous breadth. The height of the face is moderate, and therefore its form appears decidedly low. The nose is often concave or straight, seldom convex. The noses of the women are decidedly concave. Its elevation over the face is slight. The point of the nose is short.

The dimensions of the head of the Kwakiutl are similar to those of the northern types, but the head seems to be slightly smaller. The face shows a remarkably different type, which distinguishes it fundamentally from the faces of all the other groups. The breadth of face is nearly the same as that of the northern type, but its height is enormous. The same may be said of the nose, which is very high and comparatively narrow. The point of the nose is short: its elevation is also very great. The nasal bones are strongly developed, and form a steep arch, their lower ends rising high above the face. For this reason convex noses are found very frequently among this type. Convex noses also prevail among the women, and for this reason the difference between the female form of the Kwakiutl and the female form of the northern type is very great.

The Thompson River type is characterised by a very small head, both diameters being much shorter than those found on the coast, while the proportions are nearly the same. The transversal diameter of the face is much shorter than that of the coast Indians, being nearly the same as that found among the Indians on the plains. The face is much lower than that of the Kwakiutl type, and also slightly lower than that of the northern type. The nose is convex and heavy. Its point is much longer and heavier than the point of the noses of the coast types.

There are good indications of the existence of a few other types, but they cannot be distinguished with certainty from the types enumerated here. It is probable that further measurements will show that the tribes of Harrison Lake and the Gulf of Georgia represent a fourth type.

The distribution of the types of man in British Columbia has an important bearing upon the much discussed question of the classification of mankind; while some anthropologists have maintained that all classification must be based upon considerations of language, others maintain as rigorously that the main consideration must be that of physical type. The data collected by the Committee show clearly that neither of these contentions is entirely correct. We have seen that certain tribes—such as the Bilqula, who linguistically belong to the Salish group—physically belong to another group. This shows that the two phenomena do not go hand in hand, but that they constantly overlap. The classification of mankind according to physical characteristics takes into consideration only the effects of heredity and environment upon the physical type of man. Race mixture, isolation, and effect of environment will be reflected in the results of these classifications. But there are evidently cases in which a slow infiltration of foreign blood takes place, while language and customs remain unaltered or changed to but a slight extent. The Bilqula branched off from the Coast Salish at an early time, and retain the Salish language; but there has been an infiltration of Kwakiutl blood and of Athapaskan blood, which has entirely changed the physical features of the tribe. With this infiltration of foreign blood came foreign words and foreign cultural elements, but they were not sufficiently powerful to change the original speech of the people.

It is clear, from these considerations, that the three methods of classifying mankind—that according to physical characters, according to language, and according to culture—all reflect the historical development of races from different standpoints; and that the results of the three classifications are not comparable, because the historical facts do not affect the three classes of phenomena equally. A consideration of all these classes of facts is needed when we endeavour to reconstruct the early history of the races of mankind.

It will be sufficient to point out in this place a few of the more general results of the studies conducted by the Committee on the cultures of the primitive people of British Columbia. In the Reports of the Committee only brief abstracts were given of the mythologies and traditions of the tribes, but full collections were made; and a comparison of these has led to the following results:—The culture of the coast tribes of the Province is quite uniform. It has reached its highest development in the district extending from Queen Charlotte Islands to northern Vancouver Island. As we depart from this region, a gradual change in arts and customs takes place, and together with it we find a gradual diminution in the number of myths which the distant tribes have in common with the people of British Columbia. At the same time a gradual change in the incidents and general character of the legends takes place.

We can in this manner trace what we might call a dwindling-down of an elaborate cyclus of myths to mere adventures, or even to incidents of adventures, and we can follow the process step by step. Wherever this distribution can be traced, we have a clear and undoubted example of the gradual dissemination of a myth over neighbouring tribes. The phenomena of distribution can be explained only by the theory that the tales have been carried from one tribe to its neighbours, and by the tribe which has newly acquired them in turn to its own neighbours. It is not necessary that this dissemination should always follow one direction ; it may have proceeded either way. In this manner a complex tale may dwindle down by gradual dissemination, but new elements may also be embodied in it.

It may be well to give an example of this phenomenon. The most popular tradition of the North Pacific coast is that of the raven. Its most characteristic form is found among the Tlingit, Tsimshian, and Haida. As we go southward, the connection between the adventures becomes looser, and their number less. It appears that the traditions are preserved quite fully as far south as the north end of Vancouver Island. Farther south the number of raven-tales which are known to the Indians diminishes very much. At Nahwitti, near the north point of Vancouver Island, thirteen tales out of a whole of eighteen exist. The Comox have only eight, the Nootka six, and the Coast Salish only three. Furthermore, the traditions are found at Nahwitti in the same connection as farther north, while farther south they are very much modified. The tale of the origin of daylight, which was liberated by the raven, may serve as an instance. He had taken the shape of the leaf of a cedar, was swallowed by the daughter of the owner of the daylight, and then born again ; afterwards he broke the box in which the daylight was kept. Among the Nootka, only the transformation into the leaf of a cedar, which is swallowed by a girl and then born again, remains. Among the Coast Salish the more important passages survive, telling how the raven by a ruse compelled the owner of the daylight to let it out of the box in which he kept it. The same story is found as far south as Grey's Harbour in Washington. The adventure of the pitch, which the raven kills by exposing it to the sunshine, intending to use it for calking his canoe, is found far south, but in an entirely new connection, embodied in the tradition of the origin of sun and moon.

But there are also certain adventures embodied in the raven myths of the north, which probably had their origin in other parts of America. Among these may be mentioned the tale of how the raven was invited and reciprocated. The seal puts his hands near the fire, and grease drips out of them into a dish, which he gives to the raven. Then the latter tries to imitate him, but burns his hands, &c. This tale is found, in one or the other form, all over North America, and there is no proof that it originally belonged to the raven myth of Alaska. Other examples may be found in the collection of traditions published by F. Boas.[1]

The proposition that dissemination has taken place among neighbouring tribes will probably not encounter any opposition. Starting from this point of view, we may advance the following considerations :—

If we have a full collection of the tales and myths of all the tribes of a certain region, and then tabulate the number of incidents which all the collections from each tribe have in common with any selected tribe, the number of common incidents will be the larger the more intimate the relation of the two tribes, and the nearer they live together. This is what we observe in a tabulation of the material collected on the North Pacific coast. On the whole, the nearer the people, the greater the number of common elements of traditions ; the farther apart, the less their number.

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[1] *Indianische Sagen von der Nord-Pacifischen Küste Amerikas*, pp. vi–363. Berlin, 1895.

But it is not the geographical location alone which influences the distribution of tales. In some cases, numerous tales which are common to a certain territory stop short at a certain point, and are found beyond it in slight fragments only. These limits do not by any means coincide with the linguistic divisions. An example of this kind is the raven legend, to which reference has been made. It is found in substantially the same form from Alaska to northern Vancouver Island; then it suddenly disappears almost entirely, and is not found among the southern tribes of Kwakiutl lineage, nor on the west coast of Vancouver Island, although the northern tribes, who speak the Kwakiutl language, have it. Only fragments of these legends have strayed farther south, and their number diminishes with increasing distance. There must be a cause for such a remarkable break. A statistical inquiry shows that the northern traditions are in close accord with the tales of the tribes as far south as the central part of Vancouver Island, where a tribe of Salish lineage is found; but farther they do not go. The closely allied tribes immediately south do not possess them. Only one explanation of this fact is possible, viz., lack of assimilation, which may be due to a difference of character, to continued hostilities, or to recent changes in the location of the tribes, which has not allowed the slow process of assimilation to exert its deep-acting influence. The last may be considered the most probable cause. The reason for this opinion is, that the Bilqula, another Salish tribe, who have become separated from the people speaking related languages, and who live in the far north, still show in their mythologies close relations to the southern Salish tribes, with whom they have many more traits in common than their neighbours to the north and to the south. If their removal had taken place very long ago, this similarity in mythologies would probably not have persisted, but they would have been quite amalgamated with their new neighbours.

We may also extend our comparisons beyond the immediate neighbours of the tribes under consideration by comparing the mythologies of the tribes of the plateaus in the interior, and even of those farther to the east, with those of the coast. Unfortunately, the available material from these regions is very scanty. Fairly good collections exist from the Athapaskan tribes, from the tribes of Columbia River, and—east of the mountains—from the Omaha, and from some Algonkin tribes. When comparing the mythologies and traditions which belong to far-distant regions, we find that the number of incidents which they have in common is greater than might have been expected; but some of those incidents are so general that we may assume that they have no connection, and may have arisen independently. There is, however, one very characteristic feature which proves beyond cavil that this is not the sole cause of the similarity of tales and incidents. We know that in the region under discussion two important trade routes reached the Pacific coast—one along the Columbia River, which connected the region inhabited by Shoshonean tribes with the coast, and indirectly led to territories occupied by Siouan and Algonkin tribes; another one which led from Athapaskan territory to the country of the Bilqula. A route of minor importance led down Fraser River. A study of the traditions shows that along these routes the points of contact of mythologies are strongest, and rapidly diminish with increasing distances from these routes. On Columbia River the points of contact are with the Algonkin and Sioux; among the Bilqula they are with the Athapaskan. This phenomenon can hardly be explained in any other way than by assuming that the myths followed the line of travel of the tribes, and that there has been dissemination of tales all over the continent. The tabulations which have been made include the Micmac of Nova Scotia, the Eskimo of Greenland, the Ponca of the Mississippi Basin, and the Athapaskan of Mackenzie River ; and the results give the clearest evidence of extensive borrowing.

The identity of a great many tales in geographically contiguous areas has led to the assumption that, wherever a great similarity between two tales is found in North America, it is more likely that it is due to dissemination than to independent origin.

But without extending these theories beyond the clearly demonstrated truths of transmission of tales between neighbouring tribes, we may reach some further conclusions. When we compare, for instance, the legend of the culture hero of the Chinook, and that of the origin of the whole religious ceremonial of the Kwakiutl Indians, we find a very far-reaching resemblance in certain parts of the legends, which makes it certain that these parts are derived from the same source. The grandmother of the divinity of the Chinook, when a child, was carried away by a monster. Their child became the mother of the culture-hero, and by her help the monster was slain. In a legend from Vancouver Island a monster, the cannibal spirit, carries away a girl, and is finally slain by her help. Their child becomes later on the new cannibal spirit. There are certain intermediate stages of these stories which prove their identity beyond doubt. The important point in this case is that the myths in question are perhaps the most fundamental ones in the mythologies of these two tribes. Nevertheless, they are not of native growth, but —partly at least—borrowed. A great many other important legends prove to be of foreign origin, being grafted upon mythologies of various tribes. This being the case, it follows that the mythologies of the various tribes as we find them now are not organic growths, but have gradually developed and obtained their present form by accretion of foreign material. Much of this material must have been adopted ready made, and has been adapted and changed in form according to the genius of the people who borrowed it. The proofs of this process are so ample that there is no reason to doubt the fact. We are therefore led to the opinion that, from mythologies in their present form, it is impossible to derive the conclusion that they are mythological explanations of phenomena of nature observed by the people to whom the myths belong, but that many of them, at the places where we find them now, never had such a meaning. If we acknowledge this conclusion as correct, we must give up the attempts at offhand explanation of myths as fanciful, and we must admit that also explanations given by the Indians themselves are often secondary, and do not reflect the true origin of the myths.

It may be well to explain this point of view a little more fully. Certainly the phenomena of nature are the foundation of numerous myths, else we should not find that the sun, moon, clouds, thunderstorm, the sea, and the land play so important a part in all mythologies. But it seems that the specific myth cannot be simply interpreted as the result of observation of natural phenomena. Its growth is much too complex. In most cases the present form has undergone material change by disintegration and by accretion of foreign material, so that the original idea is at best much obscured.

Perhaps the objection might be raised to this argument that the similarities of mythologies are due, not only to borrowing, but also to the fact that, under similar conditions which prevail in a limited area, the human mind creates similar products. While there is a certain truth in this argument, so far as elementary forms of human thought are concerned, it seems quite incredible that the same complex product should originate twice in a limited territory. The very complexity of the tales and their gradual dwindling down, to which reference has already been made, cannot possibly be explained by any other theory than by that of dissemination. Wherever geographical continuity of the area of distribution of a complex ethnographical phenomenon is found, the laws of probability exclude the theory that in this continuous area the complex phenomenon has arisen independently in various places; but they compel us to assume that the distribution of this phenomenon in its present complex form is due to dissemination, while its composing elements may have originated here and there.

In the Old World, wherever investigations on mythologies of neighbouring tribes have been made, the philological proof has been considered the weightiest; that is to say, the proof of borrowing has been considered the most satisfactory whenever, together with the stories, the names of the actors have also been borrowed. We cannot expect to find such borrowing of names to prevail to a great extent in America. Even in Asia the borrowed names are often translated from one language into the other, so that their phonetic resemblance is entirely destroyed. The same phenomenon is observed in America. In many cases the heroes of myths are animals, whose names are introduced in the myths. In other cases, names are translated, or so much changed, according to the phonetic laws of various languages, that they can hardly be recognised. Cases of transmission of names are, however, by no means rare. We will give only a few examples from the North Pacific coast.

Almost all the names of the Bilqula mythology are borrowed from the Kwakiutl language. A portion of the great religious ceremony of the Kwakiutl has the name 'tlōkoa'la.' This name, which is also closely connected with a certain series of myths, has spread northward and southward over a considerable distance. Southward we find it as far as the Columbia River, while to the north it ceases with the Tsimshian; but still farther north another name of a part of the ceremonial of the Kwakiutl is substituted, viz., 'nō'ntlEm.' This name, as designating the ceremonial, is found far into Alaska. But these are exceptions; on the whole, the custom of translating names and of introducing names of animals excludes the application of the linguistic method of investigating the borrowing of myths and customs.

We will next consider the social organisations of the coast tribes in connection with certain peculiar customs which have been described in the Reports of the Committee, viz., the secret societies.

The northern tribes have maternal institutions, and are divided into a number of clans, which have animal totems. The clans are not considered descendants of the totem animal, but claim that the ancestor of each clan had a meeting with the totem animal, in which the latter became his friend and helper. The Kwakiutl are divided into a number of clans, most of which have animals for their totems. Most of these totems are explained in the same manner as those of the northern tribes, while others are considered direct descendants of the totem animal. Among the

Kwakiutl we find a mixture of paternal and maternal institutions, but the son is not allowed to use his father's totem ; he acquires the right to his totem by marriage, receiving at that time the totem of his wife's father. When, later on, his daughter marries, the right to the totem descends upon her husband. In this manner the totem descends in the maternal line, although indirectly. Each clan has a certain limited number of names. Each individual has only one name at a time. The bearers of these names form the nobility of the tribe. When a man receives the totem of his father-in-law, he at the same time receives his name, while the father-in-law gives up the name, and takes what is called 'an old man's name,' which does not belong to the names constituting the nobility of the tribe.

Among the Kwakiutl and Bilqula this social organisation holds good during the summer, while during the winter ceremonials it is suspended. During this time the secret societies take the place of the clans. According to tradition, these societies have originated in the same manner as the clan originated. One of the ancestors of the clan met the presiding spirit of one of the societies, and was initiated by him. This seems to be the general form of tradition explaining the origin of secret societies among all North American tribes. All those who have been initiated by the same spirit, and who have received from him the name, privileges, and secrets of the ceremonial, form a secret society. The most important among the societies on the North Pacific coast are those of the cannibals, the bears, the fools, and the warriors. The number of names composing a secret society is limited in the same manner as the number of names composing the clan. Membership in a secret society may be obtained in two ways : by marriage, in the same way as the acquisition of the totem ; and by killing the owner of a certain name. Totem and secret society are not connected inseparably ; but the one may be transferred to one person, the other to another.

In order to understand this curious system clearly we must remember that the Salish tribes which are found south of the Kwakiutl are divided into village communities ; while their northern neighbours—the Tsimshian, the Haida, and the Tlingit—are divided into maternal clans. The Kwakiutl have been strongly influenced from both sides.

The traditions explaining the totems and the secret societies refer, as stated before, to the initiation of the ancestor of the clan. They are analogous to the traditions of the acquisition of the Manitou. All the tales referring to this subject have approximately the following incident : A youth undergoes a ceremonial fasting and purification, and thus acquires the faculty of seeing a spirit, who becomes his protector. The traditions of the coast tribes explaining the origin of clans have the same contents. There is only one difference : the protecting spirit has appeared to the ancestor of the clan, and is now inherited by their descendants without personal initiation. In this respect the similarity between the traditions of the secret societies and those referring to the Manitous is much closer, since it is necessary that each new member be initiated by the presiding spirit of the society. Therefore every new member has to undergo the same ceremonies which other Indians undergo at the time of reaching puberty. The beliefs of the Chinooks of Columbia River are similar to those of the northern tribes, although among them the idea of the acquisition of the totem has been more clearly preserved. They believe that a man can acquire only that spirit who belonged to his ancestors in the paternal line, but the relation of this spirit to the individual is identical with that of the Manitou to the eastern Indian.

It can be clearly shown that the development of the family Manitou into the family totem has taken place owing to the influence of the northern tribes. In order to make this clear, it is necessary to consider for a moment the clans of the Kwakiutl somewhat closely. In examining the names of the tribes, it will be seen that very often the name of the tribe is the collective form of the name of its ancestor. At the same time a subdivision of the tribe, one of its clans, may have the name 'The Family of the Ancestor,' while the other clans have different names. It seems that this proves that the first clan formed the original stock of the tribe, and that the other clans joined it later on. This theory is strengthened by two considerations: first, it is stated that each clan originally had its village at a certain place, which it left later on in order to join others. Almost all these places can be proved to be ancient village sites. Secondly, many clans have names which may be translated, as 'Inhabitants of such and such a place,' while nowadays they live with the rest of the tribe in the same village, and have no distinct claims to the territory the name of which they bear. This seems to prove that the present social organisation of the tribe is a late development, and that originally the Kwakiutl were in the same stage of development as their southern neighbours, among whom the social unit is the village community, and who have no crests.

The northern tribes have clearly defined totems, which are inherited in the maternal line, and which have animal names and animal crests. While among these tribes the totem of the whole clan is founded on the tradition belonging to the whole clan, the subdivisions of the latter are explained in exactly the same manner as those of the Kwakiutl clans. The artistic bent of these people has taken hold of these traditions, and has thus formed the crest for the clan and for its subdivisions. There is little doubt that the plastic art of the northern tribes was a most important factor in developing their social system. In the south, where this art begins to disappear, the village community takes the place of the clan with animal totem, while among the tribes located between these two groups, among whom the plastic art is well developed, although not as highly as in the north, there is an intermediate form of social system. It is therefore likely that the development of the social system discussed here has taken place in the northern part of British Columbia.

The northern tribes of Kwakiutl lineage show clearly that their ideas have been influenced by the animal totem of the northern tribes. They have adopted to a great extent the maternal descent and the division into animal totems of the northern tribes. The social organisation of the Hē'iltsuk·, one of the most northern tribes of Kwakiutl lineage, is similar to that of the Tsimshian, while their southern neighbours, the inhabitants of Rivers Inlet, who speak the same dialect, retain the more complex organisation of the Kwakiutl; but they have mainly maternal descent.

It is an interesting fact that a great many of the clan legends of the Kwakiutl are very insignificant, while others have important mythical bearings by which they are closely connected with the mythological concepts of the people. It seems probable that clan legends first found their way to the Kwakiutl by marriages with women of northern tribes, whose traditions, according to the customs of the northern region, were inherited by the woman's children. This must have given an important impulse to acquiring or inventing similar traditions on the part of other clans, since their possession was undoubtedly considered a prestige. Probably the fastings of young men and the subsequent hallucinations have furnished the greater part of the material for these legends.

It is necessary to consider at this place a few characteristic traditions which belong to the cannibal society of the tribes of the northern and central parts of the coast. The most widely diffused tradition on this subject seems to have originated among the Hē'iltsuk·, but it has spread southward to the Kwakiutl. It is told that a young girl was carried away by the cannibal spirit. Her four brothers searched for her, and with difficulty escaped the pursuing cannibal spirit. Finally, they succeeded in killing him, and his ashes were transformed into mosquitoes. In the course of their visit to their sister the brothers learned the songs and secrets of the cannibal society. This tradition is given in most cases as the origin of the secret society. A number of other members were initiated in other ways, one by stealing the cedar-bark ornaments of the bathing cannibal spirit, another one by ascending the sky and obtaining the secrets of the society.

These customs have also spread to the northern neighbours of the Hē'iltsuk·, the Tsimshian. They have the following tradition in regard to the origin of the society :—A hunter pursued a bear, which finally led him into the interior of a rock. Inside he saw people performing the ceremonies of the society, and he was instructed by their chief to repeat the same ceremonies at home. In all the traditions of the Kwakiutl the cannibal spirit presides over the society, while he does not appear in the Tsimshian tradition. This shows that different traditions are used for explaining the same ceremonial.

In connection with these facts we will consider the conclusions which were drawn from a consideration of the mythologies of the tribes of British Columbia. We saw that none of these could be considered as the product of a single tribe. All the traditions were full of foreign elements, which it was possible to trace over wide areas. If, therefore, the same ritual is explained by different traditions, we may conclude that the ritual preceded the tradition ; that the former is the primary phenomenon, the latter the secondary.

It seems that the development of the ritual, as well as of the traditions connected with it, is founded in the prestige given by membership in a secret society. There must have developed a desire to become a member of a society, which led, wherever the number of societies was insufficient for the tribe, to the establishment of new ones. It is not meant, of course, that the Indians intentionally invented new traditions, but that the desire stimulated their fancy and excited their mind, and that in this manner, after proper fastings, occasion was given for hallucinations, the material of which was naturally taken from the ideas found among the tribe and its neighbours. Similar phenomena have been treated, from a systematic point of view, by Stoll in his book on Suggestion, and by Tarde in his book on the Laws of Imitation.

It is easily understood how the exciting ceremonial of the cannibal society may have given rise to hallucinations in which a young man thought to see the same spirit under new conditions, and that after his return from the solitude he told his visions. Since the opinion prevailed that the spirit which appeared in this manner had a tendency to reappear to the descendants of the person to whom it once appeared, opportunity was given for the formation of a new place in the secret societies. We may assume, therefore, that, psychologically, the development of the complex system of membership in the secret societies must be explained as due to the combined action of the social system and the method of acquiring guardian spirits.

While these considerations may explain the variety of form of the secret societies, and show that the myths on which a ritual is founded are probably secondary, they do not explain the origin of the societies themselves and of the peculiar customs connected with them. There are, however, indications which lead to the opinion that these societies developed from methods of warfare. First of all, it is important to note that the deity Winā'lagyilis of the Kwakiutl presides over the whole ceremonial. This name means 'the one who makes war upon the whole world,' and his spirit controls the mind of the Indians also during the time of war. For this reason the secret societies are in action also on war expeditions, no matter at what season of the year they may occur. All the oldest songs of the secret societies refer to war. The cannibal, as well as the bear dancers and the fool dancers of the Kwakiutl, are considered warriors, and go into ecstasies as soon as an enemy has been killed. All this indicates that originally the secret societies were closely connected with war expeditions.

One thing more must be considered. The customs which we observe to-day are evidently the modern development of ancient forms. It is known that the ceremonial cannibalism, which nowadays is the principal part of the whole ceremonial, has been introduced very recently among all the tribes. The Kwakiutl state that this custom was introduced among them not longer than sixty years ago, and that it originated among the Hē'iltsuk·. We also know that the custom spread from the Hē'iltsuk· to the Tsimshian not longer than a hundred and fifty years ago. Therefore there is no doubt that the custom was originally confined to the small territory of the Hē'iltsuk·. Among the southern tribes the cannibals originally confined themselves to holding with their teeth the heads of enemies which had been cut off.

The form in which the cannibalism spread from the Hē'iltsuk· is mainly the following:—A slave was killed by his owner, then he was torn to pieces and eaten by the cannibals; or pieces of flesh were bitten out of the arms and the chest of people; or, finally, corpses which had been prepared in a particular way were devoured by the cannibals. The first of these customs clearly bears some relation to war. A slave was obtained in war by the relative of a cannibal, and by killing him the owner celebrated the victory before the assembled tribe. It is not possible to prove definitely that the secret societies developed in this manner from customs related to war expeditions, but the close relationship of the two cannot be doubted.

We may say, therefore, that the investigations of the Committee have proved that dissemination of cultural elements has taken place all along the North Pacific coast, and also that the most distant parts of the American continent, and probably even parts of the Old World, have contributed to the growth of the culture of the Indians of British Columbia. This fact shows that we cannot accept the sweeping assertion that sameness of ethnical phenomena is *always* due to the sameness of the working of the human mind, but that it is necessary to consider in all anthropological investigations the important element of dissemination of cultural elements.

The decorative art of the Indians of the North Pacific coast differs from the arts of other primitive people in that the process of conventionalisation has not led to the development of geometric designs, but that the ornaments mostly represent animals. It is generally assumed that all the animal representations found on totem poles or on decorations of household utensils and of wearing apparel represent the totems of the various clans. While it is certainly true that in most cases the artists decorate the objects with the totem of the owner, there are a number of cases in which the reason for applying certain animal designs is founded on other considerations. This is very evident in the case of the fish-club, which is used in despatching halibut and other fish before they are hauled into the canoe. Almost all the clubs that I have seen represent the sea-lion or the killer-whale—the two sea animals which are most feared by the Indians, and which kill those animals that are to be killed by means of the club. The idea of giving the club the design of the sea-lion or killer-whale is therefore rather to give it a form appropriate to its function, and perhaps, secondarily, to give it by means of its form great efficiency.

Another instance in which a close relation exists between the function of the object and its design is that of the grease dish. Small grease dishes have almost invariably the shape of the seal, or sometimes that of the sea-lion; that is, of those animals which furnish a vast amount of blubber. Grease of sea animals is considered a sign of wealth. In many cases abundance of food is described by saying that the sea near the houses was covered with the grease of the seal, the sea-lion, and whales. Thus the form of the seal seems to symbolise affluence.

Other grease dishes and food dishes have the form of canoes, and here, I believe, a similar idea has given rise to the form. The canoe symbolises that a canoe load of food is presented to the guests, and that this view is probably correct is indicated by the fact that in his speeches the host often refers to the canoe filled with food which he gives to his guests. The canoe form is often modified, and a whole series of types can be established forming the transition between canoe dishes and ordinary trays. Dishes of this sort always bear a conventionalised face at each short end, while the middle part is not decorated. This is analogous to the style of the decoration of the canoe. The design represents almost always the hawk. I am not certain what has given origin to the prevalence of this design. On the whole, the decoration of the canoe is totemistic. It may be that it is only the peculiar manner in which the beak of the hawk is represented which has given rise to the prevalence of this decoration. The upper jaw of the hawk is always shown so that its point reaches the lower jaw and turns back into the mouth. When painted or carved in front view, the beak is indicated by a narrow wedge-shaped strip in the middle of the face, the point of which touches the lower margin of the chin. The sharp bow and stern of a canoe with a profile of a face on each side, when represented on a level or slightly rounded surface, would assume the same shape. Therefore it may be that originally the middle line was not the beak of the hawk, but the foreshortened bow or stern of the canoe. This decoration is so uniform that the explanation given here seems to be very probable.

On halibut hooks we find very often decorations representing the squid. The reason for selecting this motive must be looked for in the fact that the squid is used for baiting the hooks.

I am not quite certain if the decoration of armour and weapons is totemistic or symbolic. Remarkably many helmets represent the sea-lion, many daggers the bear, eagle, wolf, and raven, while I have not seen one that represents the killer-whale, although it is one of the ornaments that are most frequently shown on totemistic designs.

I presume this phenomenon may be accounted for by a consideration of the ease with which the conventionalised forms lend themselves to decorating certain parts of implements. It is difficult to imagine how the killer-whale could be represented on the handle of a dagger without impairing its usefulness. On the other hand, the long thin handles of ladles made of the horn of the big horn sheep generally terminate with the head of a raven or of a crane, the beak being the end of the handle. This form was evidently suggested by the slender tip of the horn, which is easily carved in this shape. The same seems to be true in the cases of lances or knives, the blades of which are represented as the long, protruding tongues of animals; but it may be that in this case there is a complex action of a belief in the supernatural power of the tongue, and in the suggestions which the decorator received from the shape of the object he desired to decorate.

To sum up, it seems that there are a great number of cases of decoration which cannot be considered totemistic, but which are either symbolic or suggested by the shape of the object to be decorated. It seems likely that totemism was the most powerful incentive in developing the art of the natives of the North Pacific coast; but the desire to decorate in certain conventional forms once established, these forms were applied in cases in which there was no reason and no intention of using the totemistic mark. The thoughts of the artists were influenced by considerations foreign to the idea of totemism. This is one of the numerous ethnological phenomena which, although apparently simple, cannot be explained psychologically from a single cause, but are due to several factors.

The treatment of the animal design is very peculiar. We may distinguish two principles which govern the form of representation: First, the animal is characterised by a number of symbols; secondly, the artist does not endeavour to render a perspective view of the animal, but rather to show the whole animal.

The first of these principles is probably founded largely on the difficulty encountered in designing realistic representations of various animals which would be clearly recognised as specific animals. For this reason the most characteristic peculiarities of each species become the symbols by which it is recognised. Thus the beaver is always symbolised by two large incisors and a scaly tail; the dog-fish, by an elongated forehead, a mouth with depressed corners, and five curved lines (the gills) on each cheek; the killer-whale, by its tail, flippers, and its large dorsal fin; the sculpin, by two spines which rise over the forehead; the hawk, by a large beak, which is turned backward so that it touches the chin. Probably all these symbols were originally applied to characterise a portion of a quadruped, bird, or fish; but in course of time they came to be considered as sufficient to call to mind the form of the whole animal. We find, therefore, that gradually the symbols were to a great extent substituted for representations of the whole animal. A dorsal fin worn on the blanket of a dancer, or painted on his face, indicates that the person so decorated personates the killer-whale. A strongly curved beak painted on a gambling-stick symbolises that the stick is meant to represent the thunder-bird. A protruding tongue painted on the chin symbolises the bear.

The second principle seems to be quite opposed to the first one. When the artist decorates any object with the representation of an animal, he distorts and dissects the animal in such a way as to show the whole body on the decorative field ; but a closer examination of this tendency proves that it originates mainly in the necessity felt by the artist of introducing all the symbols, which are distributed over the whole body of the animal, in the decoration. To give a few instances, bracelets are decorated in such a way that the animal is split along its back, and then represented in such a manner as to make it appear as though the arm were pushed through the opening. On tattooings the animals are shown as split through along their backs or along their chests, and then flattened out, so that a symmetrical design results. Carvings on totem poles must be interpreted in the same way, the animal being represented as bisected along the rear side of the totem pole, and extended so that the two margins of the cut appear on the borders of the carved portion of the pole. The distortion and section of animals is nowhere carried further than in representations on boxes, on slate dishes, and on Chilcat blankets ; but in all these decorations we recognise the endeavour to bring such forms of the animal into view as are essential for an understanding of the design—that is to say, all those parts of the animal are represented which serve as its symbols.

So far as I am aware, the process of conventionalising has not led to the formation of geometrical designs, which are exceedingly rare on decorated objects from the North Pacific coast. They are found only in certain kinds of basket work and in mattings.

Finally, it may be well to add a brief explanation of the economic system prevailing among these Indians, which was fully set forth in the Fifth Report of the Committee. This system finds its expression in the so-called 'potlatch.' The meaning of this custom has been much misunderstood, and the recent enactment of a law making the potlatch a criminal offence is probably in great measure due to a misconception in regard to its meaning.

The economic system of the Indians of British Columbia is largely based on credit, just as much as that of civilised communities. In all his undertakings the Indian relies on the help of his friends. He promises to pay them for this help at a later date. If the help furnished consisted in valuables, which are measured by the Indians by blankets as we measure them by money, he promises to repay the amount so loaned with interest. The Indian has no system of writing, and therefore, in order to give security to the transaction, it is performed publicly. The contracting of debts, on the one hand, and the paying of debts, on the other, is the potlatch. This economic system has developed to such an extent that the capital possessed by all the individuals of the tribe combined exceeds many times the actual amount of cash that exists ; that is to say, the conditions are quite analogous to those prevailing in our community : if we want to call in all our outstanding debts, it is found that there is not by any means money enough in existence to pay them, and the result of an attempt of all the creditors to call in their loans results in disastrous panic, from which it takes the community a long time to recover.

It must be clearly understood that an Indian who invites all his friends and neighbours to a great potlatch, and apparently squanders all the accumulated results of long years of labour, has two things in his mind which we cannot but acknowledge as wise and worthy of praise. His first object is to pay his debts. This is done publicly and with much ceremony, as a matter of record. His second object is to invest the fruits of his labour so that the greatest benefit will accrue from them for himself as well as for his children. The recipients of gifts at this festival receive these as loans, which they utilise in their present undertakings, but after the lapse of several years they must repay them with interest to the giver or to his heir. Thus the potlatch comes to be considered by the Indians as a means of insuring the well-being of their children if they should be left orphans while still young. It is, we might say, their life insurance.

The sudden abolition of this system—which in all its intricacies is very difficult to understand, but the main points of which were set forth in the preceding remarks—destroys therefore all the accumulated capital of the Indians. It undoes the carefully planned life-work of the present generation, exposes them to need in their old age, and leaves the orphans unprovided for. What wonder that it should be resisted with vigour by the best class of Indians, and that only the lazy should support it, because it relieves them of the duty of paying their debts?

But it will be said that the cruel ceremonies connected with some of the festivals make their discontinuance necessary. An intimate knowledge of the Indian character leads me to consider that any interference with these very ceremonials is unadvisable. They are so intimately connected with all that is sacred to the Indian that their forced discontinuance will tend to destroy what moral steadiness is left to him. It was during these ceremonies that I heard the old men of the tribe exhort the young to mend their ways; that they held up to reprobation the young women who had gone to Victoria to lead a life of shame; and that they earnestly discussed the question of requesting the Indian Agents to help them in their endeavour to bring the young back to the good, moral life of old.

And the cruelty of the ceremonial exists alone in the fancy of those who know of it only by the exaggerated descriptions of travellers. In olden times it was a war ceremony, and captives were killed and even devoured; but with the encroachment of civilisation the horrors of the old ceremonies have died out. An old chief has been heard addressing his people thus: 'How lovely is our time! No longer do we go in fear of each other; peace is everywhere. No longer is there the strife of battle; we only try to outdo each other in the potlatch,' meaning that each tries to invest his property in the most profitable manner, and particularly that they vie with each other in honourably repaying their debts.

The ceremony of the present day is no more and no less than a time of general amusement, which is expected with much pleasure by young and old. But enough of its old sacredness remains to give the Indian, during the time of its celebration, an aspect of dignity which he lacks at other times. The lingering survivals of the old ceremonies will die out quickly, and the remainder is a harmless amusement that we should be slow to take away from the native, who is struggling against the overpowerful influence of civilisation.

emales

42	43	44	45	46	47	48	49	50	51	52
Mary	Mary	Caroline	Lucie	Lucie	—	Agathe	Lucie	Anne	—	Mathilde
Pemberton Meadows	Anderson Lake	Seton Lake	Anderson Lake, Nk'ă'it	Anderson Lake	Seton Lake	Anderson Lake, Nk'ă'it	Seton Lake	Seton Lake	Anderson Lake, Nk'ă'it	Seton Lake
F.	F.	F.	F.	F.	F.	F.	F.	F.	F	F.
30	31	33	35	40	50	50	50	55	60	70
m	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
542[3]	1,482[3]	1,598	1,621	1,479[3]	1,556	1,507	1,463	1,474	1,429	1,348
286	1,240	1,334	1,347	1,239	1,326?	1,238	1,186	1,226	1,180	1,096
666	655	707	699	633	756	592	636	688	682	631
604	1,546	1,604	1,666	1,526	1,668	1,522	1,461	1,588	1,539	1,464
804	800	789	836	791	800	799	744	762	718	666
328	330	350	385	348	310?	361	323	330	335	345
177	175	181	184	173	181	180	172	178	188	183
153	152	147	146	164	148	157	157	155	151	148
109	120	113	120	111	106	124	120	101	118	139
134	139	138	142	147	145·5	147	139	137	142	110
46	45	49	44	49	50	56	55	49	53	53
32	34	34	38	39	38	38	32	37	39	36
6·4	86·9	81·2	79·3	94·8	81·8	87·2	91·3	87·1	80·3	80·9
1·3	86·3	81·9	84·5	75·5	72·8	84·4	86·3	73·7	83·1	79·2
9·6	75·6	77·3	86·4	79·6	76·0	67·9	58·2	75·5	73·6	67·9
3·2	44·3	44·2	43·1	42·8	48·5?	39·2	43·6	46·8	48·0	46·7
4·1	104·3	100·4	102·8	103·2	107·2	101·0	100·0	107·8	107·7	108·6
2·5	54·1	49·3	51·6	53·4	51·3	52·9	51·0	51·8	50·6	49·3
1·4	22·3	21·9	23·8	23·5	19·9?	23·9	22·1	22·4	23·6	25·6

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th shoes on spruce boughs.

[6] Father of No. 41.

1. Stlatlumh

a. Pemberton Meadows, Anderson Lake, Seton Lake

I. Males

No.	1	2	3	4	5	[illegible]	7	8	[illegible]	10	11	12	13
Name	Albert	Alceste	Tlaqlas	Jean Baptiste	Walter	Samuel Bell	Shimo	Achille	Joseph Bell	Patrick	Joseph	Michel	Joseph
Tribe	Anderson Lake	Anderson Lake	Anderson Lake	Seton Lake (?)	Pemberton Meadows	Anderson Lake, Nk'a'tl	Seton Lake	Seton Lake	Anderson Lake, Nk'a'tl	Seton Lake	Anderson Lake, Nk'a'tl	Seton Lake (?)	Pemberton Meadows
Observer	F	F	F	F	F	F	F	F	F.	F	F.	F.	F
Age	5	7	8	9	9	11	14	18	19	20	20	25	25
Height standing	1,042[1]	[illegible]	1,182[3]	1,270	1,279	1,448	1,466	1,651	1,770	1,747	1,580	1,604	1,650
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,182	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	530	[illegible]	658	672	678	624	676	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,478	1,527	[illegible]	[illegible]	[illegible]	1,640	1,711	1,692
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	738	751	811	871	844	848	[illegible]	834
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	312	[illegible]	[illegible]	408	406	[illegible]	400	[illegible]
[illegible]	166	178	[illegible]	175	172	197	178	181	189	183	176	177	181
Breadth of head	147	150	152	149	160	167	161	167	167	165	163	166	158
Height of face	89	95	95	113	106	109	110	118	116	120	118	115	110
Breadth of face	118	[illegible]	122	[illegible]	[illegible]	[illegible]	141	[illegible]	145	146	144	145	[illegible]
Height of nose	37	37	36	46	42	44	49	56	48	56	50	52	49
Breadth of nose	[illegible]	[illegible]	[illegible]	[illegible]	32	[illegible]	36	[illegible]	[illegible]	[illegible]	40	41	40
[illegible]	88.6	84.2	[illegible]	[illegible]	[illegible]	84.7	90.5	86.8	[illegible]	90.2	[illegible]	88.1	[illegible]
[illegible]	75.4	[illegible]	77.9	84.7	79.7	73.4	[illegible]	79.2	[illegible]	[illegible]	[illegible]	79.3	[illegible]
[illegible]	[illegible]	[illegible]	97.2	78.3	76.2	77.3	73.5	[illegible]	75.0	67.9	80.0	78.8	81.6
[illegible]	[illegible]	42.0	[illegible]	[illegible]	42.6	45.0	43.1	42.1	[illegible]	45.1	41.6	[illegible]	[illegible]
[illegible]	[illegible]	104.6	[illegible]	100.0	[illegible]	102.1	104.1	102.3	105.0	[illegible]	103.8	106.2	102.6
[illegible]	63.5	[illegible]	51.2	[illegible]	51.8	50.9	51.1	51.5	49.4	48.2	[illegible]	[illegible]	[illegible]
[illegible]	26.0	22.8	[illegible]	[illegible]	22.9	21.5	[illegible]	23.6	23.0	21.2	21.2	25.0	24.9

No.	14	15	16	17	18	19	20	21	22	23	24	25	26
Name	Jean Baptiste (?)	Jimmy	Johnny	Tommy Jack	Joseph	[illegible]	Edward	Johnny	John Bell	Paul		Bill	Thomas
Tribe	Seton Lake	Anderson Lake, Nk'a'tl	Anderson Lake	Anderson Lake	Anderson Lake	Anderson Lake, Nk'a'tl	Anderson Lake	Anderson Lake	Seton Lake	Bridge River, [illegible] Seton Lake	Pemberton Meadows	Anderson Lake, Nk'a'tl	Anderson Lake
Observer	F	F	F	F	F	F	B	F	F	F.	F	F	B
Age	27	30	30	30	31	35	40	40	50	65	65	65	70
Height standing	1,636	1,608	1,570[4]	1,681[5]	1,602[5]	1,618	1,700	1,676	1,582[6]	—	1,641[3]	1,536	1,476
[illegible]	[illegible]	[illegible]	1,270	1,330	1,310	[illegible]	[illegible]	[illegible]	1,290		[illegible]	[illegible]	[illegible]
[illegible]	596	[illegible]	651	604	[illegible]	594	614	[illegible]	572	—	600	524	500
[illegible]	1,705	[illegible]	1,725	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,651		[illegible]	1,640	1,570
[illegible]	[illegible]	[illegible]	[illegible]	851	[illegible]	[illegible]	806	808	828		[illegible]	816	770
[illegible]	386	372	[illegible]	368	[illegible]	415	[illegible]	[illegible]	[illegible]		[illegible]	380	[illegible]
[illegible]	182	[illegible]	[illegible]	182	182	188	192	172	188	190	179	[illegible]	[illegible]
Breadth of head	167	162	162	164	163	157	158	163	161	164	166	148	167
Height of face	121	121	127	120	115	114	129	110	113	122	110	117	106
Breadth of face	118	147	148	150	[illegible]	157	[illegible]	144	153	155	148	116	149
Height of nose	50	51	53	47	51	47	50	50	56	67	57	59	62
Breadth of nose	42	40	45	42	[illegible]	[illegible]	42	[illegible]	[illegible]	42	[illegible]	[illegible]	40
[illegible]	[illegible]	[illegible]	87.6	[illegible]	84.1	83.5	82.1	[illegible]	85.7	86.3	87.2	87.1	85.8
[illegible]	81.8	82.1	85.8	80.0	80.1	72.6	81.3	76.4	73.9	78.7	81.1	80.1	71.1
[illegible]	84.0	75.5	[illegible]	89.4	74.5	[illegible]	81.0	78.0	[illegible]	78.7	[illegible]	81.1	76.9
[illegible]	[illegible]	[illegible]	45.6	46.0	[illegible]	[illegible]	[illegible]	45.5	46.0		43.4	48.3	46.1
[illegible]	104.2	101.7	[illegible]	108.3	[illegible]	106.4	[illegible]	107.4	105.3	—	102.7	110.1	[illegible]
[illegible]	[illegible]	[illegible]	53.2	54.0	[illegible]	52.5	50.9	[illegible]	52.4	—	[illegible]	53.0	52.4
[illegible]	21.6	[illegible]	21.8	23.3	23.8	25.6	[illegible]	[illegible]	24.1	—	22.1	24.7	[illegible]

II. Females

No.	27	28	29	30	31	32	33	34	35	36	37	38	[illegible]
Name	James	Antoine	Tommy	Susanne	Sallie	Achille	Anne	Agathe	Brigitte	Susanne	Cecilia	Bridget	Bridget
Tribe	Anderson Lake, Nk'a'tl	Anderson Lake, Nk'a'tl	Anderson Lake, Nk'a'tl	Anderson Lake	Anderson Lake	Seton Lake	Seton Lake	Seton Lake	Seton Lake	Seton Lake	Anderson Lake	Anderson Lake	Anderson Lake
Observer	F	F	F	F	F	F	F	F	F	F	F.	F	F.
Age	70	80	80	8	12	18	20	22	23	27	28	28	28
Height standing	1,532	—	—	1,296[6]	1,346[4]	1,582	1,520	1,504	1,493	1,586	1,538[7]	1,491	1,677
[illegible]	[illegible]			[illegible]	[illegible]	1,322	1,258	1,212	1,223	1,323	1,278	1,212	[illegible]
[illegible]	570		—	715	611	686	[illegible]	644	630	718	677	[illegible]	722
[illegible]	1,618		—	1,316	1,449	1,622	[illegible]	[illegible]	1,568	[illegible]	[illegible]	1,565	[illegible]
[illegible]	778	—		[illegible]	623	789	810	766	[illegible]	[illegible]	[illegible]	787	811
[illegible]	381		—	280	316	373	[illegible]	325	[illegible]	[illegible]	[illegible]	370	374
[illegible]	181	182	176	165	171	175	181	169	[illegible]	188	186	172	174
Breadth of head	143	166	167	152	155	148	167	154	147	157	164	147	154
Height of face	110	110	107	92	90	115	112	109	102	111	106	106	108
Breadth of face	141	144	140	127	128	[illegible]	138	136	[illegible]	144	142	135	146
Height of nose	51	54	52	41	42	47	43	49	41	44	40	49	48
Breadth of nose	41	43	43	34	32	[illegible]	34	41	[illegible]	41	41	[illegible]	[illegible]
[illegible]	[illegible]	85.7	89.2	92.4	90.6	84.6	85.8	91.1	[illegible]	83.5	[illegible]	85.5	88.5
[illegible]	76.9	76.4	76.4	72.4	70.3	82.7	[illegible]	80.1	73.4	77.1	74.6	78.5	74.0
[illegible]	80.4	79.6	82.7	82.9	76.2	68.1	[illegible]	63.3	87.8	93.2	102.5	75.5	77.1
[illegible]	45.3	—	-	41.9	45.5	43.4	45.7	42.9	41.6	45.4	44.0	42.2	45.7
[illegible]	105.6	—	-	101.5	107.6	102.5	104.7	102.7	101.0	101.3	103.6	104.5	102.9
[illegible]	50.8		-	[illegible]	[illegible]	49.9	55.2	51.1	51.0	53.0	50.8	52.8	51.3
[illegible]	21.8			21.5	23.4	[illegible]	23.4	21.7	24.4	[illegible]	[illegible]	23.5	25.7

No.	40	41	[illegible]	[illegible]	44	45	46	47	48	49	50	51	52
Name	Susanne	Christine	Mary	Mary	Caroline	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Matilda
Tribe	Seton Lake	Seton Lake, Stlaō't	Pemberton Meadows	Anderson Lake	Seton Lake	Anderson Lake, Nk'a'tl	Anderson Lake	Seton Lake	Anderson Lake, Nk'a'tl	Seton Lake	Seton Lake	Anderson Lake, Nk'a'tl	Seton Lake
Observer	F.	F	F	F	F	F	F	F	F	F	F	F	F
Age	29	29		[illegible]	[illegible]	[illegible]	40	50	50	50	55	60	70
Height standing	1,547	1,456[4]	1,642[8]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,463	1,474	1,429	1,348
[illegible]	1,252	1,243	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,186	1,226	1,180	[illegible]
[illegible]	709	656	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	766	[illegible]	646	688	[illegible]	641
[illegible]	1,679	1,517	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,665	1,522	1,461	1,588	[illegible]	1,464
[illegible]	[illegible]	768	[illegible]	[illegible]	[illegible]	[illegible]	791	800	[illegible]	744	762	718	666
[illegible]	354	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	323	[illegible]	[illegible]	[illegible]
[illegible]	183	175	177	[illegible]	181	181	171	[illegible]	[illegible]	172	178	188	183
Breadth of head	149	161	153	152	147	146	164	148	157	157	155	151	148
Height of face	112	110	109	120	113	120	111	106	124	120	101	118	139
Breadth of face	138	134	[illegible]	[illegible]	138	142	147	[illegible]	147	[illegible]	137	142	110
Height of nose	46	44	46	45	49	44	49	50	56	55	49	53	53
Breadth of nose	39	38	32	[illegible]	[illegible]	[illegible]	[illegible]	38	38	32	37	39	36
[illegible]	81.4	92.0	86.4	[illegible]	81.2	79.3	[illegible]	81.5	87.2	91.3	87.1	80.3	80.9
[illegible]	81.2	82.1	[illegible]	[illegible]	81.9	84.5	76.5	72.8	94.4	86.3	73.7	83.1	79.2
[illegible]	84.8	86.4	[illegible]	75.6	77.3	86.4	79.6	76.0	67.9	58.2	75.5	73.6	67.9
[illegible]	45.7	43.7	[illegible]	44.1	44.2	43.1	42.8	48.5	39.2	43.6	46.8	48.0	46.7
[illegible]	108.5	101.1	104.1	104.3	100.4	102.8	103.2	107.2	101.0	100.0	107.8	107.7	108.6
[illegible]	51.2	51.2	52.5	54.1	[illegible]	[illegible]	53.4	51.3	52.9	51.0	51.8	50.6	49.3
[illegible]	23.8	22.9	21.4	[illegible]	21.9	23.8	23.5	19.9	23.9	22.1	22.4	23.6	25.6

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[1] Son of No. 18, measured [illegible] spruce boughs.

[2] Son of No. 16, measured with shoes on spruce boughs.

[3] Measured with shoes on spruce boughs.

[4] Mother of No. 1.

[5] Father of No. 2, left leg short; measured with shoes on spruce boughs.

[6] Daughter of No. 22.

[7] Father of No. 1, measured with shoes on spruce boughs.

[8] Father of No. 41.

95	96	97	98	99	100	101	102	103	104	105
Pauline	Louise	Stuwitlka'tkoa	Anne	Annie	Adèle	K'stōnī'nek	Elizabeth	Sā'ltkoa	Aline	Caroline
Bridge River	Fountain	Bridge River	Bridge River	Fountain	Fountain	Fountain	Fountain	Fountain	Lillooet	Lillooet
F.	B.	B.	F.	B.	B.	B.	B.	B.	F.	B.
30	35	40	60	60	60	60	65	65	70	70
mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1,494	1,550	1,570	1,328	1,487	1,517	1,563	1,480	1,492	1,480	—
1,238	1,297	1,274	1,056	1,205	1,241	1,281	1,226	1,229	1,194	—
618	674	662	584	675	671	667	634	654	676	—
1,485	1,581	1,560	1,375	1,571	1,555	1,560	1,456	1,508	1,545	—
808	835	866	708	764	793	792	760	746	720	—
336	344	372	295	340	319	348	313	336	332	—
173	186	186	164	176	183	190	178	182	180	189
150	159	150	153	151	148	159	153	155	148	154
112	119	118	101	109	114	113	126	114	113	109
139	149	142	133	140	140	150	144	141	143	144
49	51	45	45	52	45	54	54	52	48	50
36	32	37	36	35	33	44	37	38	41	40
86·7	85·5	80·6	93·3	85·8	80·9	83·7	86·0	85·2	82·2	81·5
80·6	79·9	83·1	75·9	77·9	81·4	75·3	87·5	80·9	79·0	75·7
73·5	62·7	82·2	80·0	67·3	73·3	81·5	68·5	73·1	85·4	80·0
41·5	43·5	42·2	43·9	45·3	44·1	42·8	42·8	43·9	45·7	—
99·7	102·0	99·4	103·6	105·6	102·5	100·0	—	101·1	104·4	—
54·2	53·9	55·2	53·2	51·3	52·2	50·8	51·4	50·1	48·6	—
22·6	22·2	23·7	22·2	22·8	21·0	22·3	21·1	22·6	22·4	—

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[8] Mother of No. 56.

1. *Stlatlumh* (continued)

b. *Lillooet, Bridge River, Fountain, Pavilion.*

I. Males

Number	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
Name	[illegible]	[illegible]	Stanislas	Hyacinthe	Joachim	Stephen	[illegible]	Jamie Donald	Johnny	Patrick	Henry Andrew	Samson	Skanetu'aq	Charlie	[illegible]	Jackson	Chief Jimmy	John	Jim	Ko'r'q	Tak'ai	Tlgapo'ê	Capt. Charlie	Pöpayl'
Tribe	Lillooet	Lillooet	Lillooet	Lillooet	Lillooet	Lillooet	M Ntlakya'pamuq F Lillooet	Fountain	Bridge River	Fountain	F Ntlakya'pamuq M Lillooet	Lillooet	Bridge River	Fountain	Bridge River	Lillooet	Lillooet	Lillooet	Bridge River	Bridge River	Bridge River	Bridge River	Lillooet	Bridge River
[illegible]	F	F	F	B	F	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Age	7	7	9	9	11	11	13½	20	20	23	28	35	35	40	40	40	40	40	58	60	60	60	60	70
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	1,254	[illegible]	[illegible]	[illegible]	1,318	[illegible]	1,454[2]	1,712	1,603	1,771	[illegible]	1,645	1,603	[illegible]	1,569	1,607	1,625[3]	1,671	[illegible]	1,585	1,786	1,570	1,563	1,643
Height of shoulder	[illegible]	[illegible]	1,007	960	1,060	1,073	1,190	[illegible]	1,320	1,451	1,309	-	1,340	1,324	1,266	1,294	1,332	1,454	1,370	1,315	1,322	1,245	1,260	1,376
Length of arm	[illegible]	[illegible]	567	622	578	550	658	775	715	815	[illegible]		712	725	701	709	712	711	743	715	748	761	700	715
Finger reach	[illegible]	[illegible]		1,212	1,380	1,306	1,541	1,811	1,621	1,922	1,666	1,738	1,654	1,679	1,650	[illegible]	[illegible]	1,718	[illegible]	1,600[6]	[illegible]	1,722	1,639	1,681
Height sitting	[illegible]	[illegible]	650	622	[illegible]	704	7?6	920	853	923	886	835	840	850	804	875	863	908	882	818	815	792	828	846
Width of shoulders	261	254	[illegible]	[illegible]	224	204	312	[illegible]	380	408	402	382	386	368	385	363	396	394	406	370	369	400	375	344
Length of head	174	168	176	170	173	172	187	182	179	191	180	187	189	192	182	190	192	188	197	190	196	192	185	187
Breadth of head	157	152	160	153	155	149	145	158	162	167	161	166	162	157	147	163	154	159	174	164	168	151	157	160
Height of face	99	101	104	106	105	102	118	120	126	123	118	119	118	123	111	129	123	130	124	121	119	119	115	121
Breadth of face	127	[illegible]	127	[illegible]	130	[illegible]	128	161	148	[illegible]	[illegible]	160	156	141	149	149	146	147	[illegible]	161	163	150	[illegible]	144
[illegible]	42	[illegible]	[illegible]	42	48	44	51	[illegible]	52	55	51	55	54	[illegible]	50	67	67	67	53	57	64	64	57	55
[illegible]	[illegible]	[illegible]	38	31	38	31	32	42	38	[illegible]	38	38	40	38	[illegible]	39	34	35	41	37	44	44	37	38
Length breadth index	90·2	[illegible]	90·9	90·0	89·6	86·6	77·6	86·8	90·5	87·4	89·9	88·4	85·7	81·8	80·8	85·8	80·2	84·6	88·3	86·3	81·0	78·6	84·9	80·2
Facial index	[illegible]	[illegible]	[illegible]	83·3	[illegible]	77·9	[illegible]	[illegible]	85·1	80·4	85·5	[illegible]	75·6	87·2	79·9	86·6	84·2	88·4	81·0	80·1	77·8	79·3	75·2	84·0
Nasal index	81·0	77·5	76·9	[illegible]	79·2	77·3	62·7	84·0	73·1	70·9	74·5	[illegible]	74·1	67·9	86·0	68·4	59·6	61·4	77·1	68·5	81·5	81·5	64·9	69·1
[illegible]	[illegible]	42·2	44·6	41·5	42·6	42·3	45·1	[illegible]	44·7	46·0	43·6	–	44·6	44·5	44·0	44·0	[illegible]	42·6	44·2	45·0	47·1	48·5	44·9	44·8
Index of finger reach	[illegible]	[illegible]	[illegible]	100·8	102·4	100·8	105·4	105·9	103·5	108·4	101·9	105·6	101·2	102·9	105·2	101·4	105·8	102·9	104·2	–	109·2	109·7	104·7	102·3
Index of height sitting	[illegible]	[illegible]	51·2	51·8	[illegible]	54·2	50·8	53·8	[illegible]	52·1	[illegible]	[illegible]	52·5	[illegible]	51·2	[illegible]	53·0	54·7	52·5	51·4	51·3	50·4	53·1	51·5
Index of width of shoulders	[illegible]	[illegible]	[illegible]	22·2	21·8	22·6	21·6	22·0	21·8	21·0	25·1	24·2	24·1	22·6	24·5	22·5	24·3	23·1	24·2	22·0	23·2	25·5	22·8	21·0

II. Females

Number	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
Name	Celestine	Agnes	Thérèse	Louise	Nancy	Lucy	Mathilde	Rosalie	Francisca	Sophie	Lucy	Angélique	[illegible]	Helena	Ethel	Célestine	Susanne	[illegible]	[illegible]	Louise	Stuwitlka'tkoa	Anne	Annie	Adele	[illegible]	Elizabeth	[illegible]	Aline	Caroline
Tribe	Fountain	Fountain	Fountain	Fountain	Fountain	Bridge River	Fountain	Fountain	Pavilion	Fountain	Fountain	Fountain	Bridge River	Pavilion	Bridge River	Lillooet	Lillooet	Bridge River	Bridge River	Fountain	Bridge River	Bridge River	Fountain	Fountain	Fountain	Fountain	Fountain	Lillooet	Lillooet
[illegible]	B	B	B.	B	B	F	B.	B	B	B	B	B	B	B.	B	B	B.	B	F	[illegible]	B	F	B	B	B	B	B	F	B
Age	5	8	12	13	14	15	16	18	20	20	20	22	22	22	23	25	26	30	30	[illegible]	40	60	60	60	60	65	65	70	70
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	974	1,174	1,244	1,528	1,520	1,464	1,623	1,570	1,552	1,550	1,470	1,542	1,533	1,606	1,632[7]	1,576	1,558[8]	[illegible]	1,494	1,550	1,570	1,328	1,457	1,517	1,563	1,480	[illegible]	1,480	
Height of shoulder	717	948	1,030	1,243	1,227	1,182	1,317	1,319	1,250	1,236	1,200	1,276	1,282	1,325	1,280	1,320	1,282	1,252	[illegible]	1,297	1,274	1,076	[illegible]	1,241	1,281	1,226	1,220	1,194	
Length of arm	411	502	[illegible]	662	687	640	712	684	[illegible]	693	651	688	672	675	697	716	689	[illegible]	618	674	662	584	675	671	667	634	654	676	
Finger reach	965	1,164	1,307	1,577	1,581	1,515	1,675	1,602	1,590	1,606	1,548	1,617	1,603	[illegible]	1,600	1,646	1,614	1,600	1,485	1,581	1,560	[illegible]	1,571	[illegible]	[illegible]	1,456	1,508	1,545	
Height sitting	525	615	690	793	785	749	870	827	780	807	764	813	823	831	808	794	804	774	808	835	866	708	764	791	792	760	746	720	·
Width of shoulders	222	258	286	330	342	329	375	356	358	346	345	369	316	370	360	382	380	338	[illegible]	344	372	295	340	313	348	313	[illegible]	432	
Length of head	164	167	166	181	177	166	185	172	185	181	174	178	176	181	181	168	181	179	173	186	186	164	176	188	190	178	182	180	189
Breadth of head	148	139	141	150	153	146	156	155	155	154	156	157	149	149	149	146	156	148	150	159	150	153	151	148	159	153	153	148	154
Height of face	91	101	101	112	108	114	110	109	116	112	105	107	111	117	117	108	118	113	112	119	115	104	109	114	113	126	114	113	109
Breadth of face	119	116	123	133	131	135	141	144	138	143	138	144·5	140	134	140	135	142	141	139	149	142	133	140	110	150	144	141	143	144
[illegible]	38	42	46	44	52	46	51	44	46	46	42	42	46	48	49	39	45	46	49	51	45	45	52	45	54	54	52	46	50
[illegible]	28	25	26	32	33	36	39	37	36	36	35	36	34	37	33	34	34	36	36	32	37	36	35	43	44	37	36	41	40
Length breadth index	90·2	83·5	84·9	82·9	86·4	88·0	84·3	90·1	83·8	85·1	89·7	88·2	84·7	82·3	82·3	86·9	86·2	82·7	86·7	85·5	80·6	93·3	85·8	80·9	83·7	86·0	[illegible]	82·2	81·5
Facial index	76·5	87·1	82·1	84·2	82·4	84·4	84·4	75·7	84·1	78·3	76·1	74·1	79·3	87·3	83·6	80·0	83·1	80·1	80·6	79·9	83·1	75·9	77·9	81·4	75·3	87·5	80·9	79·0	75·7
Nasal index	73·7	59·5	56·5	72·7	63·5	78·2	76·5	84·1	78·3	78·3	83·3	85·7	74·0	68·8	67·4	87·2	75·6	78·3	73·5	62·7	82·2	80·0	67·3	73·9	81·5	68·5	73·1	85·4	80·0
[illegible]	42·2	42·9	41·5	43·3	45·2	43·5	44·0	43·6	44·7	44·7	44·3	45·0	43·3	41·9	45·6	45·6	44·2	45·6	41·5	43·5	42·2	43·9	45·[illegible]	44·1	42·8	42·8	43·9	45·7	—
Index of finger reach	99·0	99·4	101·8	103·2	104·1	103·1	103·2	102·0	102·5	103·6	105·3	105·6	104·6	103·8	104·4	104·5	103·6	106·3	99·7	102·0	99·4	103·6	105·6	102·5	100·0	—	101·1	104·4	
Index of height sitting	53·9	55·1	53·9	51·8	51·6	51·0	53·7	52·7	50·3	52·1	52·0	53·1	53·8	51·6	52·8	50·6	51·5	51·3	54·2	53·9	55·2	53·2	51·3	52·2	50·8	51·4	50·1	48·6	
Index of width of shoulders	22·8	22·1	22·3	21·6	22·5	22·4	23·1	22·7	23·1	22·3	23·5	24·1	20·7	23·0	23·5	24·3	24·4	22·4	22·6	22·2	23·7	22·2	22·8	21·0	22·3	21·1	22·6	22·4	-

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[1] Son of No. 93.

[2] Son of No. 60.

[3] Son of No. 70.

[4] Father of No. 58.

[5] Father of No. 59.

[6] One hand stiff.

[7] Daughter of No. 10 (II.).

[8] Mother of No. 56.

1. *Stlatli* *Tribes.*

c. *Stlatliumн*

	II. Females					
Number . . .	11	12	13	14	15	16
Name	Andresi	Athanasie	Christine	K·'ēqpā'tkoa	Kultsi'Qa	Nicapa'tko
Tribe	F. Stlā'tliumн M. Stlaqā'yuQ	F. Stlā'tliumн M. NtlakyapamuQ'ō'e	F. Shuswap M. Stlā'tliumн	F. Shuswap M. Stlā'tliumн	F. ½ Shuswap ½ Stlā'tliumн M. Stlā'tliumн	F. ½ Stlā'tliumн ½ Stlemqō'lequmq M. Stlā'tliumн
Observer . .	B.	B.		B.	B.	B.
Age . . .	11	19	23	40	45	55
	mm.	mm.	mm.	mm.	mm.	mm.
Height standing .	1,343	1,587	1,553	1,612	1,503	1,592
Height of shoulder	1,080	1,285	1,263	1,360	1,220	1,310
Length of arm .	586	682	690	681	672	662
Finger-reach . .	1,373	1,643	1,625	1,618	1,612	1,605
Height sitting .	711	786	794	860	800	793
Width of shoulders	284	372	332	328	337	354
Length of head .	170	174	174	174	186	185
Breadth of head .	149	147	147	143	148	157
Height of face .	107	116	114	120	103	106
Breadth of face .	128	136	133	137	141	145
Height of nose .	45	48	48	54	47	46
Breadth of nose .	29	34	34	41	36	36
Length-breadth index	87·6	84·5	84·5	82·1	79·6	84·8
Facial index . .	83·6	85·3	85·7	87·6	73·0	73·1
Nasal index . .	64·4	70·8	70·8	75·9	76·6	78·3
Index of arm . .	43·7	42·9	44·5	42·3	44·8	41·6
Index of finger-reach	102·2	103·5	104·6	100·4	107·3	100·8
Index of height sitting	53·1	49·4	51·2	53·4	53·3	49·9
Index of width of shou	21·2	23·4	21·4	20·4	22·5	22·3

1. [illegible] Half-bloods

2. Stl'atl'umH mixed with Shuswap and other Tribes

	M[illegible]		I. Males												II. Females			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	5	[illegible]	[illegible]	8	9	10	11	12	13	14	[illegible]	16
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Athanase	Christine	[illegible]	Kaitsi'qa	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F. Shuswap M. Stl'atl'umH	[illegible]	[illegible]	[illegible]
[illegible]	F	F	B	B	B	B	B	B	B	B	[illegible]	B	[illegible]	I		B	B	B
No.	7	25	9	11	15	20	24	30	39	40	65	70	[illegible]	19	23	[illegible]	[illegible]	55
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,146[1]	1,592	1,240	1,347	1,582	1,702	1,771	1,675	1,603	1,609	—	1,6[illegible]	[illegible]	1,587	[illegible]	[illegible]	[illegible]	[illegible]
Height of shoulder	901	1,298	—	1,098	1,294	1,398	1,462	1,380	1,290	1,293	—	1,222	1,080	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Length of arm	471	671	—	601	704	718	760	763	682	677	—	686	596	682	690	681	672	[illegible]
Finger reach	1,160	1,606	—	1,390	1,659	1,760	1,831	1,761	1,627	1,615	—	1,685	[illegible]	[illegible]	1,625	1,618	[illegible]	[illegible]
Height sitting	636	864	635	704	830	900	940	864	880	873	—	783	711	[illegible]	734	860	800	[illegible]
Width of shoulders	253	392	274	297	377	378	410	394	382	385	450	[illegible]	[illegible]	[illegible]	[illegible]	328	[illegible]	[illegible]
Length of head	176	184	170	177	185	182	191	186	186	191	187	[illegible]	170	174	174	171	[illegible]	[illegible]
Breadth of head	145	165	151	158	156	164	157	160	163	157	156	[illegible]	[illegible]	147	147	[illegible]	148	[illegible]
Height of face	91	117	96	105	114	116	122	123	131	119	132	111	107	116	114	120	[illegible]	[illegible]
Breadth of face	122	147	127	138	139	151	149	143	145	145	150	[illegible]	[illegible]	[illegible]	[illegible]	137	141	[illegible]
Height of nose	35	52	44	43	45	46	49	53	55	51	53	61	[illegible]	48	48	51	47	46
Breadth of nose	31	35	33	31	40	43	39	39	35	39	39	[illegible]	[illegible]	[illegible]	34	[illegible]	[illegible]	[illegible]
Length breadth index	82.4	89.7	88.8	89.3	84.3	90.1	82.2	86.0	88.1	82.2	83.4	[illegible]	[illegible]	84.5	84.5	82.4	79.6	[illegible]
Facial index	74.6	79.6	75.6	76.1	82.0	76.8	81.9	82.6	90.3	82.1	88.0	76.0	[illegible]	85	85.7	87.6	73.0	[illegible]
Nasal index	88.6	67.3	75.0	72.1	88.9	93.5	79.6	73.6	63.6	76.5	73.6	74.5	[illegible]	70.8	70.8	75.9	76.6	78.3
Index of arm	41.0	42.2	—	44.7	44.6	42.2	42.9	45.5	42.6	42.0	—	46.0	[illegible]	42.9	44.5	42.1	44.8	[illegible]
Index of finger reach	101.2	100.9	—	103.2	104.9	102.8	103.6	105.1	101.5	102.2	—	106.1	[illegible]	101.5	[illegible]	100.4	[illegible]	100.8
Index of height sitting	55.3	54.3	51.2	52.1	52.5	53.0	53.1	51.4	55.0	51.2	—	52.6	[illegible]	[illegible]	51.2	53.4	[illegible]	[illegible]
Index of width of shoulders	22.0	24.7	22.1	22.0	23.9	22.2	23.2	23.5	23.9	23.9		[illegible]	21.2	23.4	21.4	20.1	[illegible]	[illegible]

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[1] Son of No. 47 (I a).

[2] Father of No. 91 (I b).

2	45	46	47	48	49	50	51	52	53	54	55	56
Ta'ngEn	Chief William	Tea	Stanislas	Charlie	Jim Pelyon	Alexis	William	Maurice	Abraham	John	Joe	Adam
Alkali Lake	Soda Creek	Canoe Creek	Canoe Creek	Alkali Lake	F. Dog Creek M. Alkali Lake	Soda Creek	Canoe Creek	High Bar	Canoe Creek	Williams Lake	Williams Lake	Canoe Creek
B.	F.	F.	B.	F.	B.	F.	F.	B.	B.	F.	F.	B.
21	50	50	50	50	50	55	55	55	55	55	55	58
m	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1,69	1,683[10]	1,648[11]	1,668	1,640	1,633	1,690	1,662	1,630	1,638	1,639	1,578	1,640
1,40	1,354	1,333	1,377	1,319	1,340	1,336	1,361	1,336	1,320	1,351	1,254	1,333
78	740	718	746	741	722	764	771	707	700	704	703	735
1,86	1,752	1,708	1,717	1,744	1,718	1,647	1,774	1,680	1,600	1,704	1,666	1,696
86	838	846	846	830	864	852	863	854	822	850	846	807
40	334	370	381	391	403	358	375	378	351	375	353	369
17	183	189	185	185	192	186	189	187	191	179	190	178
16	157	161	159	165	168	155	157	148	157	161	158	155
12	118	122	118	117	118	133	127	115	115	110	120	118
15	149	154	146	153	158	143	150	147	144	152	147	148
5	53	52	49	55	54	56	55	48	53	49	51	53
4	39	38	40	42	44	38	40	39	40	42	43	42
91	85·8	85·2	85·9	89·2	87·5	83·3	83·1	79·1	82·2	89·9	83·1	87·0
81	79·2	79·2	80·8	76·5	74·7	93·0	84 7	78·2	79·9	72·4	81·6	79·7
76	73·6	73·1	81·6	76·4	81·5	67·9	72·7	81·3	75·5	85·7	84·3	79·2
46	44·0	43·5	44·7	45·2	44·3	45·2	46·4	43·4	42·7	42·9	44·5	44·9
110	104·1	103·6	102·9	106·3	105·2	97·5	106·7	103·1	97·7	104·0	105·6	103·4
51	49·9	51·3	50·7	50·6	53·0	50·4	52·0	52·4	50·1	51·8	53·5	49·2
23	19·9	22·8	22·8	23·8	24·7	21·2	22·6	23·2	21·4	22·9	22·3	22·5

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[10] Father of No. 15.

[11] Father of No. 84.

3. *St'lɛma'tl'ɛqumq*

I. Males

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Name	[illegible]	Thomas	Edward	Edward	Willie Dixon	Theodore	Ambrose	James	Henry Dixon	Paul	Sandy	Alex	Johnnie	Basil
[illegible]	Williams Lake	Williams Lake	High Bar	Alkali Lake	Alkali Lake	Soda Creek	[illegible]	Soda Creek	Alkali Lake	Canoe Creek	Soda Creek	Soda Creek	Alkali Lake	F. Canoe Creek M. Alkali Lake
[illegible]	F	B	B	B	B	B	B	B	B	B	B	B	B	B
[illegible]	[illegible]	8	8	9	9	10	10	12	12	13	14	14	15	15
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,717	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Height of shoulder	918	920	[illegible]	983	967	1,023	1,076	1,117	1,167	1,150	1,280	1,213	1,181	1,212
Length of arm	514	507	510	519	[illegible]	[illegible]	573	620	646	606	706	658	657	670
Finger reach	[illegible]	1,182	1,203	1,213	1,301	1,326	1,340	1,452	1,483	1,402	1,636	1,573	1,604	1,647
Height sitting	606	671	628	698	[illegible]	672	677	705	778	719	804	770	780	798
Width of shoulders	[illegible]	265	263	275	263	285	300	303	272	304	328	289	312	335
Length of head	165	160	168	176	178	173	171	179	182	178	188	175	177	174
Breadth of head	[illegible]	[illegible]	155	151	156	147	146	155	154	150	148	155	154	166
Height of face	96	93	[illegible]	[illegible]	110	[illegible]	104	101	109	103	114	114	111	108
Breadth of face	124	128	126	128	142	130	130	134	134	128	[illegible]	142	134	138
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41	42	45	44	48	45	[illegible]	45
Breadth of nose	32	34	34	31	35	36	34	36	35	32	37	37	38	38
[illegible] index	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84·2	78·7	87·0	87·0	[illegible]
Facial index	77·4	72·7	81·7	75·0	83·3	76·1	80·0	75·4	81·3	80·4	82·0	80·2	82·8	78·3
[illegible]	82·4	91·9	71·9	73·8	71·4	90·0	82·9	85·7	72·9	72·7	77·1	86·0	77·6	84·5
[illegible]	41·6	41·5	41·1	41·5	42·3	44·0	42·4	45·6	43·9	43·0	45·3	43·6	45·1	44·4
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	102·5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	21·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22·2	[illegible]	18·8	21·6	[illegible]	19·1	[illegible]	22·2

Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Name	Antoine	Anton	Simon	Jack	John	Felix	[illegible]	Edward	[illegible]	[illegible]	Johnson	[illegible]	Maurice	Alec
[illegible]	Soda Creek	Alkali Lake	Soda Creek	Dog Creek	Canoe Creek	[illegible]	Alkali Lake	Dog Creek	High Bar	Canoe Creek	Alkali Lake	High Bar	Canoe Creek	Sugar Cane
[illegible]	F.	B	F	B	B	B	B	B	B	B	F	B	B	B
[illegible]	16	17	18	20	20	20	21	22	24	[illegible]	27	30	32	35
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,670	[illegible]	[illegible]	[illegible]
Height of shoulder	[illegible]	1,215	[illegible]	1,164	1,330	1,375	[illegible]	1,318	1,440	1,352	1,348	[illegible]	1,373	1,367
Length of arm	774	707	733	711	714	747	756	686	745	716	731	[illegible]	754	737
Finger reach	1,786	1,665	1,716	1,732	1,713	1,775	[illegible]	1,666	1,744		1,770	1,697	1,695	1,713
Height sitting	858	857	875	890	861	[illegible]	867	886	908	860	882	901	862	893
Width of shoulders	362	373	381	367	381	402	406	360	[illegible]	378	421	379	398	380
Length of head	189	180	182	183	183	192	[illegible]	186	187	184	184	184	187	186
Breadth of head	153	149	157	158	160	158	[illegible]	163	[illegible]	160	159	[illegible]	160	153
Height of face	121	117	116	120	116	128	124	119	140	118	120	124	120	113
Breadth of face	143	119	143	150	144	144	153	138	154	146	[illegible]	150	148	147
[illegible]	[illegible]	48	47	[illegible]	49	57	55	51	[illegible]	52	45	51	51	52
Breadth of nose	38	41	40	42	42	41	42	44	42	37	37	40	39	42
[illegible] index	[illegible]	[illegible]	[illegible]	[illegible]	87·4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Facial index	84·6	81·2	80·4	80·0	[illegible]	88·9	81·0	80·1	84·4	80·8	81·1	82·7	81·1	76·9
[illegible]	77·6	85·4	85·1	82·4	85·7	71·9	76·4	[illegible]	68·9	71·2	77·4	71·4	76·6	80·8
[illegible]	45·3	45·9	45·4	45·4	43·6	43·9	46·2	42·5	42·1	43·7	43·8	44·2	44·0	44·1
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100·8		[illegible]	[illegible]	101·8	[illegible]
[illegible]	[illegible]	[illegible]	52·7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52·8	[illegible]	51	[illegible]
[illegible]	[illegible]	[illegible]	21·0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21·0	22·2	[illegible]	[illegible]	22·9

Number	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Name	Capt. Johnnie	Jack	Chief William	Peter	Jean Baptiste	Johnnie	James	Billy Harry	Charlie	[illegible]	William	Auguste	Billy	Johnnie
[illegible]	Canoe Creek	Sugar Cane	Sugar Cane	Alkali Lake	Sugar Cane	F. Dog Creek M. Alkali Lake	High Bar	F. Dog Creek M. Alkali Lake	Soda Creek	Canoe Creek	Alkali Lake	Soda Creek	Alkali Lake	Canoe Creek
[illegible]	F	B	B	B.	B.	B	B	F	B	F	B	F	F	F
[illegible]	35	35	36	37	38	40	40	40	40	40	45	45	45	45
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
[illegible]	1,675	1,614	1,710	[illegible]	1,690	1,617	[illegible]	1,681	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Height of shoulder	1,340	1,322	1,430	1,266	1,380	1,370	1,426	1,358	1,355	1,422	—	1,339	1,360	
Length of arm	720	709	764	710	772	737	739	757	708	766	—	740	745	
Finger reach	1,749	1,700	1,812	1,697	1,797	1,748	1,699	1,750	1,782	1,780	1,711	1,744	1,796	—
Height sitting	860	849	912	815	900	859	870	891	929	920	885	866	848	—
Width of shoulders	378	[illegible]	367	377	406	395	360	395	[illegible]	356	374	400	373	
Length of head	187	184	181	187	196	190	[illegible]	192	191	182	189	187	185	187
Breadth of head	156	149	161	[illegible]	157	155	162	161	157	157	153	118	156	154
Height of face	[illegible]	110	123	125	120	122	118	124	129	123	126	119	131	117
Breadth of face	118	138	148	146	151	151	155	153	153	145	142	145	144	149
[illegible]	47	[illegible]	61	55	52	55	56	52	[illegible]	[illegible]	51	46	55	50
Breadth of nose	40	40	41	35	43	42	43	39	39	41	41	37	37	38
[illegible] index	[illegible]	[illegible]	[illegible]	[illegible]	80·1	81·5	85·7	[illegible]	[illegible]	[illegible]	80·9	[illegible]	84·3	82·3
Facial index	81·1	79·7	83·1	85·6	79·5	80·8	76·1	81·0	83·7	81·8	88·0	82·1	90·9	81·8
[illegible]	85·1	81·6	66·3	63·6	82·7	76·4	86·0	75·0	70·9	82·0	80·4	80·0	67·3	76·0
[illegible]	[illegible]	44·0	44·7	45·5	45·7	45·5	45·3	45·1	41·4	44·0	—	44·6	44·3	—
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	105·1	101·4	[illegible]	[illegible]	[illegible]	[illegible]	105·3	106·9	
[illegible]	[illegible]	52·7	53·1	[illegible]	53·3	[illegible]	51·4	[illegible]	[illegible]	[illegible]	51·4	52·2	50·5	
[illegible]	[illegible]	[illegible]	21·5	21·2	24·0	24·4	21·6	23·5	[illegible]	22·8	22·8	24·1	22·2	

Number	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Name	Antoine	Samson	Chief William	[illegible]	Stanislas	Charlie	Jim Dixon	Alexis	William	[illegible]	Abraham	John	Joe	Adam
[illegible]	High Bar	Alkali Lake	[illegible]	[illegible]	Canoe Creek	Alkali Lake	F. Dog Creek M. Alkali Lake	Soda Creek	Canoe Creek	High Bar	Canoe Creek	Williams Lake	Williams Lake	Canoe Creek
[illegible]	B.	B.	F	F	B	F	B	F	F	B	B	F	F.	B.
[illegible]	45	48	50	50	50	50	50	55	55	55	55	55	55	58
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
[illegible]	[illegible]	1,544	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,578	[illegible]
Height of shoulder	1,260	1,239	1,354	[illegible]	1,377	1,313	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,254	[illegible]
Length of arm	672	683	710	[illegible]	746	741	[illegible]	764	771	707	[illegible]	734	703	715
Finger reach	1,658	1,607	[illegible]	[illegible]	1,717	1,744	[illegible]	[illegible]	[illegible]	[illegible]	1,600	1,701	[illegible]	[illegible]
Height sitting	828	831	839	[illegible]	846	830	[illegible]	[illegible]	[illegible]	854	[illegible]	850	846	807
Width of shoulders	336	373	334	370	381	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Length of head	181	182	183	189	185	185	[illegible]	[illegible]	[illegible]	187	[illegible]	[illegible]	190	178
Breadth of head	155	167	157	161	159	165	[illegible]	[illegible]	157	118	157	164	158	[illegible]
Height of face	121	111	118	122	118	117	[illegible]	[illegible]	127	115	115	110	120	118
Breadth of face	151	152	149	151	146	153	[illegible]	[illegible]	150	147	[illegible]	162	147	148
[illegible]	52	53	53	52	49		51	[illegible]	[illegible]	48	53	49	51	53
Breadth of nose	39	36	39	38	40	42	41	[illegible]	40	39	40	42	43	42
[illegible] index	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87·0
Facial index	80·1	73·0	79·2	79·2	80·8	76·5	74·7	93·0	84·7	78·2	79·9	72·4	81·6	79·7
[illegible]	75·0	66·0	73·6	73·4	81·0	76·4	81·5	67·9	72·7	81·3	75·5	85·7	84·3	79·2
[illegible]	43·1	44·4	44·0	43·5	44·7	45·2	44·3	45·2	46·4	43·4	42·7	42·9	44·6	44·9
Finger reach	[illegible]	104·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	97·5	106·7	103·1	97·7	104·0	105·6	103·4
[illegible]	[illegible]	51·0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50·4	52·0	52·4	50·1	51·5	[illegible]	[illegible]
[illegible]	21·5	24·2	19·9	22·8	22·8	[illegible]	24·7	21·2	22·6	24·2	21·1	[illegible]	[illegible]	[illegible]

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[1] Son of Nos. 47 and 94.

[2] Brother of No. 9.

[3] Brother of Nos. 8 and 69.

[4] Brother of Nos. 6 and 69.

[5] Brother of No. 5.

[6] Brother of No. 73.

[7] Son of No. 45.

[8] Father of No. 1 (IV).

[9] Father of No. 3.

[10] Father of No. 15.

[11] Father of No. 81.

102	103	104	105	106	107	108	109	110	111	112	113
Agathe	Lucy	Cécile	Amy	Madeline	Mary	Anne	Qulēsti'ks	Sarah	Mary	Bridget	Aimée
Alkali Lake	Canoe Creek	Canoe Creek	Dog Creek	High Bar	Alkali Lake	Canoe Creek	Canoe Creek	Canoe Creek	Sugar Cane	High Bar	Canoe Creek
F.	F.	F.	B.	B.	F.	B.	B.	F.	F.	B.	F.
0	50	50	50	50	55	55	58	60	65	65	70
m.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
89	1,534	1,506	1,470	1,510	1,551	1,520	1,617	1,614	1,495	1,525	—
89	1,240	1,232	1,208	1,245	1,238	1,234	1,323	1,332	1,226	—	—
21	670	664	703	665	708	686	707	751	670	—	—
38	1,540	1,507	1,570	1,550	1,621	1,571	1,633	1,644	1,520	1,543	—
66	808	792	769	780	812	800	842	790	750	807	—
45	331	333	318	314	328	330	332	345	312	337	—
82	178	172	180	174	178	178	183	175	170	187	190
57	154	145	150	149	154	153	146	155	143	149	155
17	114	112	110	111	114	115	117	117	108	109	120
44	139	137	135	136	137	139	137	147	138	141	139
49	50	49	50	45	51	50	54	52	43	52	48
36	37	35	32	35	37	39	38	37	39	35	41
·2	86·5	84·3	83·3	85·6	86·5	85·9	79·8	88·6	84·1	79·7	81·5
·2	82·0	81·8	81·5	81·6	83·2	82·7	85·4	79·6	78·3	77·3	86·3
·5	74·0	71·4	64·0	77·8	72·5	78·0	70·4	71·2	90·7	67·3	85·4
·3	43·8	44·0	47·8	44·0	45·7	45·1	43·6	46·6	45·0	—	—
·1	100·4	100·0	106·8	102·6	104·5	103·4	101·0	101·9	101·7	101·2	—
·5	52·8	52·5	52·3	51·7	52·4	52·6	52·0	49·1	50·3	53·4	—
7	21·6	22·1	21·6	20·8	21·2	21·9	20·5	21·4	20·9	22·3	—

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[16] Mother of No. 3.

3. *Stlemao Isauma* (continued).

	I. Males								
Number	57	58	59	60	61	62	63	64	65
	[illegible]	Charlie	[illegible]	Charlie	Telkan	Casimir	Bob	Chief	Thomas
	[illegible]	High Bar	Alkali Lake	Canoe Creek	Chimney Creek	F. Alkali Lake M. Dog Creek	Williams Lake	Pavilion	F. Sugar Cane M. Alkali Lake
	I	E	I	F	L	F	F	D	[illegible]
	60	60	60	60	65	63	65	68	[illegible]
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,718	1,512	1,545	[illegible]	1,704	1,528	[illegible]	1,660	—
Height of shoulder	[illegible]	1,185	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—
Length of arm	759	692	704	723	736	737	722	731	—
Finger reach		[illegible]	1,602	[illegible]	[illegible]	1,597	1,681	[illegible]	
Height sitting	901	767	785	833	855	774	816	865	—
Width of shoulders	361	356	339	380	358	368	376	361	—
Length of head	189	177	176	193	181	195	188	193	194
Breadth of head	160	159	157	166	[illegible]	165.5	149	166	164
Height of face	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	117	111	[illegible]
Breadth of face	153	119	150	154	118	154	149	117	157
Height of nose	52	55	54	55	51		56	59	57
Breadth of nose	44	40	41	41	38	—	44	44	47
Cephalic index	84.7	89.8	89.2	86.0	[illegible]	85.1	79.3	86.0	[illegible]
Facial index	[illegible]	[illegible]	[illegible]	79.7	[illegible]	70.5	78.5	77.6	[illegible]
Nasal index	84.6	72.7	75.9	74.5	71.5	—	78.6	72.9	82.5
Index of arm	[illegible]	45.8	45.7	45.6	[illegible]	48.2	43.5	44.0	—
Index of finger reach		111.3	[illegible]	105.2	[illegible]	104.4	101.1	101.9	—
Index of height sitting	52.4	50.8	51.0	52.4	50.3	50.6	49.2	52.1	—
Index of width of shoulders	21.0	23.6	22.0	23.9	21.1	24.1	22.7	21.7	—

	II. Females									
Number	66	67	68	69	70	71	72	73	74	75
	Angélique	Nancy	Susanne	Juliana	Louisa Robbins	Agnes	Eliza	Anastasie	Therese	Christine
	Alkali Lake	Soda Creek	Williams Lake	Soda Creek	Alkali Lake	Alkali Lake	Sugar Cane	Soda Creek	Alkali Lake	Alkali Lake
	L	E	I	P	D	L	F	F	L	F
	5	6	7	8	9	9	9	9	10	11
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Height of shoulder	781	754	[illegible]	934	[illegible]	917	921	[illegible]	[illegible]	[illegible]
Length of arm	396	407	461	514	621	487	505	503	644	611
Finger reach	[illegible]	[illegible]	1,104	1,194	1,245	1,164	1,214	1,219	1,276	[illegible]
Height sitting	572	544	592	636	617	628	652	646	657	670
Width of shoulders	220	210	227	273	271	261	276	268	271	290
Length of head	157	159	166	173	172	168	167	170	175	174
Breadth of head	146	141	148	143	149	144	141	[illegible]	158	152
Height of face	79	91	[illegible]	[illegible]	92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Breadth of face	111	116	121	126	127	122	128	123	134	131
Height of nose	32	39	[illegible]	36	37	37	35	39	45	40
Breadth of nose	31	29	31	33	[illegible]	29	[illegible]	31	35	[illegible]
Cephalic index	[illegible]	88.7	89.1	[illegible]	[illegible]	[illegible]	[illegible]	85.8	90.2	[illegible]
Facial index	[illegible]	78.4	75.2	71.8	[illegible]	78.7	[illegible]	[illegible]	[illegible]	[illegible]
Nasal index	96.9	74.4	83.8	91.7	89.2	78.4	97.2	87.2	77.8	85.0
Index of arm	39.2	41.0	[illegible]	44.2	42.4	42.0	42.8	[illegible]	44.2	[illegible]
Index of finger reach	[illegible]	99.3	101.8	100.7	101.5	101.7	[illegible]	[illegible]	[illegible]	101.1
Index of height sitting	56.9	54.8	51.8	53.4	52.6	51.1	55.3	51.4	53.4	52.8
Index of width of shoulders	21.6	21.2	21.0	22.0	22.0	22.5	21.7	22.9	22.2	22.8

	II. Females									
Number	76	77	78	79	80	81	82	83	84	85
	Ellen	Nellie	[illegible]	Kate	Marianne	Margaret	Aurelia	Pauline	Annie	Catherine
	Williams Lake	Alkali Lake	Soda Creek	Alkali Lake	High Bar	Canoe Creek	Alkali Lake	Alkali Lake	Alkali Lake	High Bar
	L		B	F	I	[illegible]	B	F	F	I
	11	12	12	14	15	16	17	17	17	18
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,570	[illegible]	[illegible]	[illegible]
Height of shoulder	1,184	1,107	[illegible]	[illegible]	1,219	[illegible]	1,280	[illegible]	1,256	[illegible]
Length of arm	672	603	[illegible]	599	661	704	688	702	706	746
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,703
Height sitting	767	735	[illegible]	806	793	822	826	812	826	833
Width of shoulders	318	[illegible]	[illegible]	[illegible]	[illegible]	362	340	[illegible]	365	[illegible]
Length of head	171	175	177	171	170	180	175	182	185	178
Breadth of head	[illegible]	151	[illegible]	[illegible]	[illegible]	157	146	149	156	141
Height of face	[illegible]	102	[illegible]	[illegible]	[illegible]	111	[illegible]	115	121	[illegible]
Breadth of face	132	139	[illegible]	148	142	146	[illegible]	117	[illegible]	[illegible]
Height of nose	46	41	43	47	44	46	45	47	50	44
Breadth of nose	[illegible]	[illegible]	35	35	38	38	37	38	35	[illegible]
Cephalic index	[illegible]	[illegible]	[illegible]	[illegible]	85.2	87.2	[illegible]	81.8	[illegible]	[illegible]
Facial index	[illegible]	73.4	[illegible]	[illegible]	[illegible]	[illegible]	81.1	[illegible]	[illegible]	[illegible]
Nasal index	82.6	92.7	81.4	74.5	[illegible]	82.6	82.2	80.8	70.0	75.0
Index of arm	[illegible]	[illegible]	41.8	[illegible]	44.7	[illegible]	[illegible]	45.3	44.1	[illegible]
Index of finger reach	101.7	[illegible]	106.0	96.8	[illegible]	[illegible]	[illegible]	107.7	106.2	[illegible]
Index of height sitting	52.9	51.0	50.8	56.0	53.6	[illegible]	52.6	[illegible]	52.0	51.7
Index of width of shoulders	21.9	22.8	21.1	22.4	23.1	[illegible]	21.7	21.0	23.0	22.7

	II. Females									
Number	86	87	88	89	90	91	92	93	94	95
	Mary	Marguerite	Mathilde	Mary	Margaret	Marianne	Louise	Agathe	Florentine	Cecile
	Canoe Creek	Canoe Creek	Alkali Lake	Soda Creek	Alkali Lake	Soda Creek	High Bar	Canoe Creek	High Bar	Alkali Lake
	F	F	F	F	F	F	I	F	I	F
	20	20	22	22	23	25	28	30	[illegible]	35
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	[illegible]	1,581	1,474	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Height of shoulder	[illegible]	[illegible]	[illegible]	[illegible]	1,170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Length of arm	694	717	681	665	675	709	665	[illegible]	709	679
Finger reach	[illegible]	1,658	[illegible]	[illegible]	[illegible]	1,671	[illegible]	[illegible]	[illegible]	[illegible]
Height sitting	850	825	[illegible]	817	[illegible]	855	780	[illegible]	786	[illegible]
Width of shoulders	[illegible]	345	365	[illegible]	[illegible]	378	[illegible]	348	[illegible]	[illegible]
Length of head	[illegible]	174	174	166	180	[illegible]	181	186	183	181
Breadth of head	[illegible]	153	147	[illegible]	149	158	[illegible]	154	157	154
Height of face	[illegible]	107	106	[illegible]	112	[illegible]	111	[illegible]	[illegible]	[illegible]
Breadth of face	[illegible]	[illegible]	134	133	140	[illegible]	[illegible]	[illegible]	135	145
Height of nose	46	45	47	43	[illegible]	47	46	[illegible]	54	52
Breadth of nose	[illegible]	33	[illegible]	30	30	37	[illegible]	[illegible]	[illegible]	[illegible]
Cephalic index	[illegible]	[illegible]	[illegible]	87.9	82.2	[illegible]	82.8	82.8	[illegible]	[illegible]
Facial index	[illegible]	80.4	[illegible]	78.9	80.0	81.0	77.6	[illegible]	[illegible]	[illegible]
Nasal index	[illegible]	73.3	70.2	69.8	66.7	78.7	76.1	72.9	61.8	75.0
Index of arm	[illegible]	[illegible]	[illegible]	[illegible]	46.2	43.8	43.5	[illegible]	[illegible]	[illegible]
Index of finger reach	[illegible]	[illegible]	106.5	[illegible]	[illegible]	104.2	102.6	[illegible]	[illegible]	101.6
Index of height sitting	51.5	52.2	51.6	52.7	53.4	52.8	51.0	52.9	50.7	53.6
Index of width of shoulders	22.5	21.8	[illegible]	21.7	21.4	23.3	23.1	22.0	[illegible]	[illegible]

	II. Females									
Number	96	97	98	99	100	101	102	103	104	105
	[illegible]	Anne	Louise	Julie	Mary	Therese	Agathe	Lucy	[illegible]	[illegible]
	Alkali Lake	High Bar	High Bar	Canoe Creek	Soda Creek	Williams Lake	Alkali Lake	Canoe Creek	Canoe Creek	[illegible]
	[illegible]	[illegible]	B	[illegible]	F	F	I	F	F	
	40	40	40	42	45	46	50	50	60	50
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Height of shoulder	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Length of arm	634	625	650	691	785	696	721	670	664	[illegible]
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,618	[illegible]		[illegible]	[illegible]
Height sitting	797	[illegible]	825	[illegible]	821	828	[illegible]	[illegible]	792	[illegible]
Width of shoulders	[illegible]	332	375	346	[illegible]	[illegible]	345	[illegible]	[illegible]	[illegible]
Length of head	171	190	181	169	171	183	182	178	172	180
Breadth of head	[illegible]	152	152	147	146	152	157	[illegible]	[illegible]	150
Height of face	[illegible]	125	[illegible]	[illegible]	[illegible]	120	[illegible]	[illegible]	[illegible]	[illegible]
Breadth of face	[illegible]	141	141	136	134	150	[illegible]	[illegible]	137	135
Height of nose	45	55	49	54	58	48	49	50	43	50
Breadth of nose	34	34	38	34	32	36	[illegible]	[illegible]	[illegible]	[illegible]
Cephalic index	[illegible]	80.0	[illegible]	87.0	85.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Facial index	[illegible]	88.7	[illegible]	[illegible]	[illegible]	80.0	[illegible]	[illegible]	[illegible]	[illegible]
Nasal index	75.6	61.8	77.6	[illegible]	55.2	75.0	73.5	74.0	71.4	64.0
Index of arm	[illegible]	41.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Index of finger reach	[illegible]	[illegible]	[illegible]	102.6	101.6	101.8	[illegible]	[illegible]	[illegible]	[illegible]
Index of height sitting	55.0	55.4	53.9	51.2	50.7	52.7	54.5	52.8	52.5	52.4
Index of width of shoulders	23.2	22.0	21.5	21.6	21.3	23.9	21.7	21.6	22.1	21.6

	II. Females							
Number	106	107	108	109	110	111	112	113
	[illegible]	Mary	Anne	[illegible]	Sarah	Mary	Bridget	[illegible]
	High Bar	Alkali Lake	Canoe Creek	Canoe Creek	Canoe Creek	Sugar Cane	High Bar	Canoe Creek
	I	F	B	I	F	F	[illegible]	F
	50	55	55	58	60	[illegible]	65	[illegible]
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	
Height standing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Height of shoulder	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Length of arm	665	[illegible]	[illegible]	707	751	670		—
Finger reach	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,520	1,543	
Height sitting	[illegible]	[illegible]	800	[illegible]	790	750	807	—
Width of shoulders	314	[illegible]	310	[illegible]	[illegible]	[illegible]	337	
Length of head	174	178	178	183	176	170	187	190
Breadth of head	149	151	153	146	165	143	[illegible]	155
Height of face	111	[illegible]	115	117	117	[illegible]	[illegible]	120
Breadth of face	136	137	139	137	147	138	141	139
Height of nose	45	51	50	54	52	43	52	48
Breadth of nose	35	37	39	[illegible]	37	39	35	41
Cephalic index	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84.1	[illegible]	[illegible]
Facial index	81.6	[illegible]	82.7	[illegible]	[illegible]	[illegible]	[illegible]	86.3
Nasal index	77.8	72.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85.4
Index of arm	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		—
Index of finger reach	[illegible]	[illegible]	103.4	101.0	101.9	[illegible]	101.2	
Index of height sitting	51.7	52.4	52.6	52.0	[illegible]	[illegible]	[illegible]	
Index of width of shoulders	20.8	21.2	[illegible]	20.5	[illegible]	[illegible]	[illegible]	

Sister of No. 72.

Sister of Nos. 6 and 8.

Sister of No. 68.

Sister of No. 11.

Daughter of No. 46.

Daughter of No. 7 (IV.).

Mother of No. 3.

—	I. Males							
Number	57	58	59	60	61	62	63	64
Name	Penoit	Charlie	Johnnie	Charlie	Tê'lkᴇn	Casimir	Bob	Chief
Tribe	Canoe Creek	High Bar	Alkali Lake	Canoe Creek	Chimney Creek	F. Alkali Lake M. Dog Creek	Williams Lake	Pavilion
Observer	B.	B.	B.	F.	B.	F.	F.	B.
Age	60	60	60	60	65	65	65	68
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,718	1,512	1,545	1,591	1,704	1,528	1,662	1,660
Height of shoulder	1,422	1,185	1,279	1,305	1,397	1,298	1,349	1,362
Length of arm	759	692	704	723	735	737	722	731
Finger-reach	—	1,683	1,602	1,673	1,703	1,595	1,681	1,692
Height sitting	901	767	785	833	855	774	816	865
Width of shoulders	361	356	339	380	358	368	376	361
Length of head	189	177	176	193	181	195	188	193
Breadth of head	160	159	157	166	151	165·5	149	166
Height of face	120	113	113	122	121	117	117	114
Breadth of face	153	149	150	153	148	153	149	147
Height of nose	52	55	54	55	51	—	56	59
Breadth of nose	44	40	41	41	38	—	44	43
Length-breadth index	84·7	89·8	89·2	86·0	83·4	85·1	79·3	86·0
Facial index	78·4	75·8	75·3	79·7	81·8	76·5	78·6	77·6
Nasal index	84·6	72·7	75·9	74·5	74·5	—	78·6	72·9
Index of arm	44·1	45·8	45·7	45·5	43·2	48·2	43·5	44·0
Index of finger-reach	—	111·3	103·7	105·2	100·0	104·4	101·1	101·9
Index of height sitting	52·4	50·8	51·0	52·4	50·3	50·6	49·2	52·1
Index of width of shoulders	21·0	23·6	22·0	23·9	21·1	24·1	22·7	21·7

[10] Sister of No. 72.

4. Stlemqsleqmna and Other Tribes mixed.

	I. Males							II. Females			
	1	2	3	4	5	6	7	8	9	10	11
Name	Alec	Thomas	Joseph	Peter	Alec	Tim[illegible]	Capt. Charlie	Louise	Aline	Louise	Rose
[illegible]	F. Alkali Lake M. Kenim Lake	F. Alkali Lake M. Kenim Lake	F. [illegible] Lake M. Kenim Lake	F. Alkali Lake M. Kenim Lake	F. [illegible] M. Canoe Creek	F. Kenim Lake M. Dog Creek	F. Soda Creek M. Bonaparte	F. Alkali Lake M. Kenim Lake	F. Alkali Lake M. Chilcotin	F. Carrier M. Soda Creek	F. Kenim Lake M. Soda Creek
[illegible]	F.	B.	B.	B.	B.	F.	F.	B.	F.	F.	F.
Age	12	16	[illegible]	20	35	40	55	13	33	55	65
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,446	1,580	1,614	1,630	1,690	1,676	1,656	1,453	1,605	1,567	1,450
Height of shoulder	1,157	1,290	1,318	1,344	1,395	1,481	1,358	1,203	1,312	1,281	1,177
Length of arm	673	702	748	751	737	770	710	678	682	706	700
Finger reach	1,498	1,637	1,764	1,711	1,755	1,752	1,691	1,646	1,602	1,571	1,640
Height sitting	728	836	880	853	908	871	839	770	806	755	748
Width of shoulders	340	378	354	358	378	375	336	313	355	306	320
Length of head	178	182	188	189	185	192	175	174	175	180	177
Breadth of head	148	154	154	163	159	161	165	148	157	146	150
Height of face	111	108	122	124	115	119	120	105	107	109	105
Breadth of face	134	143	145	152	152	150	147	138	139	137	144
Height of nose	45	44	50	54	51	50	51	43	46	52	48
Breadth of nose	38	38	41	42	37	39	38	32	34	35	37
Length-breadth index	83.1	84.6	81.6	86.2	85.9	83.8	94.3	85.0	89.7	81.1	84.7
Facial index	82.8	75.5	84.1	81.6	75.7	79.3	81.6	76.1	76.9	79.6	72.9
Nasal index	84.5	86.4	82.0	72.4	72.6	78.0	74.5	74.4	73.9	67.3	77.1
	46.7	44.4	46.3	46.1	43.6	45.8	42.9	46.8	42.4	45.0	48.3
Index of finger reach	103.8	103.6	109.3	105.0	103.8	104.5	102.1	106.1	99.8	100.4	106.2
Index of height sitting	50.5	52.9	54.7	51.8	53.7	51.8	50.5	53.1	50.1	48.1	51.6
Index of width of shoulders	[illegible]	23.9	22.0	22.0	22.4	22.4	20.2	21.7	22.0	19.5	22.1

5. Stl'atlumq.

	I. Males				II. Females										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name	George	Mike	Tom	Narcisse	Hélène	Célestine	Theresa	Maggie	Bridget	Augustine	Julie	Lisette	[illegible]	Celestine	Margaret
[illegible]	Kenim Lake	Kenim Lake	Kenim Lake	Kenim Lake	Kenim Lake	Kenim Lake	North Thompson	Kenim Lake	Kenim Lake	North Thompson	North Thompson	North Thompson	Kenim Lake	Kenim Lake	Kenim Lake
[illegible]	B.	B.	B.	B.	F.	F.	F.	F.	B.	B.	B.	F.	B.	B.	B.
Age	10	12	12	13	8	9	9	11	12	11	16	19	25	18	60
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,313[1]	1,285	1,413[2]	1,414[3]	1,116	1,255[4]	1,351	1,390	1,403	1,455	1,550	1,466	1,569	1,514	1,425
Height of shoulder	1,060	1,010	1,132	1,145	905	1,009	1,093	1,130	1,141	1,170	1,244	1,184	1,280	1,231	1,175
Length of arm	596	595	627	622	485	551	544	601	[illegible]	672	669	653	710	643	655
Finger reach	1,353	1,356	1,487	1,455	1,171	1,288	1,358	1,356	1,418	1,512	1,551	1,629	1,675	1,603	1,470
Height sitting	735	696	733	763	625	705	716	725	715	812	874	810	843	801	731
Width of shoulders	291	281	323	298	268	286	310	303	317	317	323	330	381	357	314
Length of head	178	176	182	178	167	171	169	169	186	179	183	187	189	179	171
Breadth of head	155	150	159	158	148	150	151	143	152	146	153	156	151	152	151
Height of face	99	111	108	99	89	98	107	98	108	113	122	114	113	110	112
Breadth of face	131	141	143	145	127	135	144	130	136	136	138	144	142	145	134
Height of nose	44	47	49	41	37	40	44	41	40	47	51	44	48	41	48
Breadth of nose	35	35	38	40	34	35	32	37	33	34	35	34	41	40	40
Length-breadth index	87.0	85.2	87.4	88.7	88.6	87.8	89.3	84.6	81.7	81.5	83.6	83.4	79.9	84.9	88.3
Facial index	75.6	78.7	75.5	68.3	70.1	72.6	74.3	75.3	79.4	83.1	88.4	79.2	79.6	75.9	83.6
Nasal index	79.6	74.5	77.6	97.6	91.9	87.5	72.7	90.2	82.5	72.4	68.6	75.0	85.4	90.9	83.3
	45.5	46.1	44.6	44.1	42.5	44.0	40.2	43.5	45.1	46.0	43.2	44.4	45.5	41.9	45.8
Index of finger reach	103.0	105.5	105.2	101.5	102.5	102.6	100.6	100.4	101.2	104.0	100.8	111.3	107.1	105.9	103.1
Index of height sitting	56.1	54.0	52.0	54.4	54.8	56.0	53.0	52.2	53.2	55.6	56.3	55.2	53.1	53.2	51.4
Index of width of shoulders	22.4	21.8	22.9	21.1	24.6	22.7	25.2	21.9	22.6	23.8	20.8	22.4	24.4	24.6	22.0

6. Kamloops.

	I. Males												II. Females							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Name	Gabriel Narcisse	George Alexis	Cyprian	Alec Joseph	Harry Duncan	Casimir Michel	Adolph William	Alexander Bob	Allen Edward	Cyprian Antony	Benjamin Thomas	Bob Pavilion	Juliana	Cécile	Mary	Marianne	Katrine	Julia	Rosa	[illegible]
[illegible]	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	F. Kamloops M. Bonaparte	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops	Kamloops
[illegible]	B.	B.	F.	F.	B.	B.	B.	B.	B.	F.	B.	B.	B.	B.	B.	F.	B.	F.	F.	F.
Age	10	11	11	13	13	14	14	11	11	17	40 (?)	41	8	9	10	12	12	12	[illegible]	[illegible]
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,258	1,465	1,230	1,382	1,436	1,367	1,370	1,426	1,171	1,115	1,700	1,615	1,198	1,301	1,245	1,332	1,362	1,150	1,184	[illegible]
Height of shoulder	1,000	1,100	970	1,118	1,172	1,076	1,105	1,150	1,172	1,132	[illegible]	1,351	945	—	987	965	1,080	[illegible]	1,214	1,275
Length of arm	720	587	556	610	641	584	588	641	[illegible]	620	768	722	521		521	609	604	671	654	722
Finger reach	1,248	1,103	1,230	1,444	1,443	1,330	1,474	1,162	1,500	1,397	1,808	1,655	1,207	1,352	1,248	1,451	1,403	1,578	1,760	[illegible]
Height sitting	663	711		715	775	747	738	754	750	[illegible]	885	875	638	710	681		715	790	800	[illegible]
Width of shoulders	268	[illegible]	290	296	311	294	293	294	331	325	380	344	271	301	269		304	341	351	371
Length of head	173	176	173	184	180	181	171	185	181	175	191	187	171	173	167.5	182	169	175	180	178
Breadth of head	155	153	146	150	147	153	153	155	153	148	158	161	145	145	147	146	145	142	148	151
Height of face	106	112	97	121	117	105	104	110	111	103	122	130	100	101	103	106	106	117	112	107
Breadth of face	127	131	127	134	129	134	136	132	138	128	153	149	124	129	127	126	126	130	135	137
Height of nose	44	51	37	46	49	43	42	48	49	43	56	57	42	40	44	43	42	44	45	47
Breadth of nose	34	33	31	31	32	33	36	35	36	34	41	38	33	30	33	32	34	35	35	37
Length-breadth index	89.6	86.9	84.4	81.9	81.6	84.5	89.5	83.8	84.5	84.5	82.7	86.1	84.8	83.8	88.2	80.2	85.8	81.1	82.2	84.8
Facial index	83.3	85.5	76.4	90.3	90.7	78.4	76.4	83.3	80.4	80.4	79.7	87.2	80.6	78.3	81.1	84.1	84.1	90.0	83.0	78.1
Nasal index	77.1	64.7	83.8	68.9	65.3	76.7	85.7	72.9	73.5	79.1	73.2	66.7	78.6	75.0	75.0	74.4	78.6	79.6	77.8	78.7
	41.5	42.8	45.2	46.4	44.0	42.6	42.6	45.0	44.5	42.8	47.2	44.6	41.4		41.8	46.1	44.1	45.0	46.9	46.5
Index of finger reach	[illegible]	102.8	104.8	104.5	100.5	101.9	100.2	102.5	104.2	104.3	[illegible]	102.8	100.7	107.9	100.0	101.4	103.0	105.9	105.1	106.1
Index of height sitting	53.5	51.9	—	51.8	52.4	53.8	53.9	52.7	51.7	51.4	52.1	54.0	53.2	54.6	54.5	—	54.0	53.0	54.1	[illegible]
Index of width of shoulders	21.6	22.4	23.6	21.4	21.6	21.5	21.4	20.6	22.8	22.0	22.4	24.0	22.8	23.2	21.5		22.3	23.1	23.7	24.3

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[1] Son of No. 36 (III.)

[2] Father of No. 89 (III.)

[3] Brother of No. 3.

[4] Brother of No. 1.

[5] Brother of No. 6.

[6] Sister of No. 4.

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7. Buonaparte

	7 Males							5 Females				
Number	1	2	3	4	5	6	7	8	9	10	11	12
Name	Pierre	Hyacinth Jules	Thomas George	Willie Jules	Edward Jules	Spo'laqen	Edward Hyacinth	Alice	Pauline	Agathe	Eliza	Victoria
[illegible]	F Pavilion M Buonaparte	Deadman's Creek	Deadman's Creek	Deadman's Creek	Deadman's Creek	F Pavilion M Buonaparte	F Buonaparte M ½ Buonaparte, ½ Cawa'qum	Deadman's Creek	Deadman's Creek	Deadman's Creek	Deadman's Creek	Deadman's Creek
	B	F	F	F	F	B	F	B	F	[illegible]	B	B
Age	4	9	10	13	15	24	34	9	10	11	13	13
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	1,022	1,155[1]	1,198	1,378[2]	1,427[3]	1,720	1,673	1,183	1,308	1,323	1,414	1,366
Height of shoulder	755	901	962	1,141	1,112	1,405	1,330	932	1,042	1,068	1,113	1,094
Length of arm	404	494	527	627	639	746	667	510	592	582	630	610
Finger-reach	1,064	1,163	1,215	1,440	1,506	1,800	1,727	1,210	1,328	1,382	1,500	1,445
Height sitting	522	598	633	730	756	914	858	663	722	716	725	727
Width of shoulders	232	266	250	310	325	397	385	274	304	350	332	318
Length of head	161	173	167	171	173	189	181	174	166	171	176	181
Breadth of head	150	149	149	150	155	160	154	145.5	139	151	156	153
Height of face	93	101	96	101	109	127	125	99	108	97	107	106
Breadth of face	124	122	121	128	134	149	141	126	127	131	138	134
Height of nose	43	45	41	43	47	53	55	44	43	43	47	43
Breadth of nose	31	33	32	32	34	41	40	32	32	31	35	34
Cephalic index	93.2	86.1	89.2	87.7	89.6	84.7	85.0	83.6	83.7	88.3	88.6	84.5
Facial index	75.0	82.8	79.3	78.9	81.2	85.2	88.7	78.6	85.0	74.0	77.5	79.1
Nasal index	72.1	73.3	78.0	74.4	72.4	77.4	72.7	72.7	74.4	72.1	74.5	79.1
Index of arm	39.5	42.8	43.9	45.4	44.8	43.4	39.9	43.2	45.2	44.1	44.7	44.7
Index of finger reach	104.1	100.7	101.4	104.5	105.5	104.7	103.2	102.2	101.5	104.4	106.1	105.7
Index of height sitting	51.0	51.8	52.8	52.9	53.0	53.1	51.4	56.2	55.1	54.2	51.3	53.1
Index of width of shoulders	22.7	22.9	20.8	22.5	22.7	23.1	23.1	23.2	23.2	26.5	23.5	23.2

8. Shuswap Half-bloods

	10 Males										11 Females										
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Name	François	Kristwish	Maurice	David Peter	André Manuel	Basil Faillardeau	Alfred Manuel	Alec Leonard	Johnnie Peter	Gabriel	Lizzie	Louise	Augusta	Annie Sam	Maggie Faillardeau	Faustine	Lizzie Ign.	Catherine	Philomena	Annie	Aimée
[illegible]	F Soda Creek M ½ White, ½ Soda Creek	F ½ Spanish, ½ Stlemqo'ltumq M Stlemqo'ltumq	F Soda Creek M ½ White, ½ Soda Creek	F ½ French, ¼ Cree, ¼ Carrier, ¼ Chilcotin M Soda Creek	F Kamloops M ½ Kamloops, ½ White	F ½ Shuswap, ½ French M Shuswap	F Kamloops M ½ Kamloops, ½ White	F White M Shuswap	F French M Shuswap	F French M Shuswap	½ White, ½ Shuswap	½ White, ½ Shuswap	F ½ French, ¼ Cree, ¼ Carrier, ¼ Chilcotin M Soda Creek	White blood	F ½ Shuswap, ½ French M Shuswap	½ White, ½ Shuswap	F English M Kamloops	White blood	White blood	F French M Shuswap	White blood
	B	B	B	B	B	F	B	B	B	B	B	B	F	F	F	F	B	B	B	B	B
Age	6	7	8	8	11	13	14	15	23	30	6	9	9	11	11	11	13	14	14	22	[illegible]
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	1,037[1]	1,277	1,192[2]	1,184[3]	1,360[4]	1,444[5]	1,422[6]	1,567	1,737[7]	1,660	1,053[8]	—[9]	1,336[10]	1,475[11]	1,328[12]	1,368	1,492	1,601[13]	1,510	1,682	1,522
Height of shoulder	803	1,038	910	912	1,093	1,162	1,135	1,270	1,450	1,336	806		1,074	1,195	1,039	1,102	1,208	1,322	1,211	1,290	1,255
Length of arm	427	540	511	501	607	669	635	678	705	694	432	—	600	662	571	602	686	706	696	752	682
Finger-reach	1,011	1,288	1,205	1,182	1,416	1,545	1,493	1,603	1,703	1,760	1,052	—	1,380	1,467	1,362	1,376	1,573	1,640	1,600	1,695	1,603
Height sitting	583	668	617	664	681	752	750	835	877	895	578	—	702	764	704	739	797	845	797	880	808
Width of shoulders	230	276	244	248	299	311	325	347	371	376	231	—	300	320	292	293	358	353	344	374	331
Length of head	168	174	174	177	180	177	176	189	197	189	160	174	167	177	177	169	181	177	189	182	181
Breadth of head	143	153	144	160	152	152	158	150	152	162	139	147	154	158	148	144	147	157	146	144	158
Height of face	95	97	102	102	105	108	111	115	124	128	91	93	104	106	100	105	107	112	113	110	108
Breadth of face	121	133	123	133	128	126	136	136	141	152	116	124	135	136	127	129	141	139	128	140	140
Height of nose	40	42	46	40	45	41	43	48	52	57	38	38	38	47	42	46	45	47	47	49	51
Breadth of nose	30	36	32	33	34	34	37	35	42	39	27	35	34	36	34	31	37	36	33	34	36
Cephalic index	85.1	87.9	82.8	90.3	84.4	85.9	89.8	79.4	77.0	85.7	86.8	84.5	92.2	89.3	83.6	85.2	81.5	88.7	77.2	79.1	87.3
Facial index	78.5	72.9	82.9	76.7	82.0	85.7	81.6	84.7	88.0	84.2	78.4	75.0	77.0	77.9	78.7	81.4	75.9	80.6	88.3	78.5	77.1
Nasal index	75.0	85.7	69.6	82.5	75.5	82.9	86.0	72.9	80.8	68.4	71.1	92.1	89.5	76.6	80.9	67.4	82.2	76.6	70.2	69.4	70.6
Index of arm	41.0	42.3	42.9	42.5	44.6	46.5	44.7	43.2	40.5	41.8	41.1	—	44.8	45.0	42.9	43.9	46.0	44.1	46.1	44.7	44.9
Index of finger reach	97.5	100.8	101.1	99.8	104.1	106.8	105.0	102.3	98.0	106.0	100.0		103.3	99.5	102.5	100.8	105.7	102.4	106.0	101.0	105.3
Index of height sitting	56.2	52.3	51.8	56.1	50.0	52.1	52.8	53.2	50.4	53.9	55.0	—	52.4	52.0	52.9	53.9	53.5	52.8	52.8	52.5	53.2
Index of width of shoulders	22.1	21.6	20.5	21.0	22.0	21.6	22.9	22.1	21.3	22.6	22.0	—	22.4	21.8	22.0	21.4	24.0	22.1	22.8	23.7	21.8

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[1] Brother of Nos. 4 and 5.

[2] Brother of Nos. 2 and 5.

[3] Brother of Nos. 2 and 4.

[1] Brother of No. 3.

[2] Brother of No. 1.

[3] Brother of No. 13.

[4] Brother of No. 7.

[5] Brother of No. 15.

[6] Brother of No. 5.

[7] Not level ground; measured with shoes.

[8] Sister of No. 12.

[9] Sister of No. 11.

[10] Sister of No. 4.

[11] Sister of No. 18.

[12] Sister of No. 6.

[13] Sister of No. 14.

						II. Females					
20	44	45	46	47	48	49	50	51	52	53	54
Johnnie	Quoste'n	Chinaman	Dick	Louis	Charlie	Sallie	Susanne	Emmeline	Minnie	Josephine	Lucy
Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin
B.	F.	F.	B.	F.	F.	B.	B.	F.	B.	F.	F.
25	55	55	55	55	55	6	9	11	12	13	20
mm	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
82	1,540	1,580	1,594	1,588	1,635[13]	1,097	1,320[14]	1,370[15]	1,317	1,487	1,580
50	1,285	1,283	1,293	1,315	1,353	840	1,037	1,131	1,045	1,210	1,315
77	644	705	708	693	731	454	575	647	596	670	722
84	—	1,636	1,686	1,591	1,695	1,092	1,348	1,504	1,383	1,518	1,652
94	816	825	835	839	845	618	727	724	717	788	799
40	360	363	380	346	323	245	266	296	298	300	314
19	178	183	186	188	184	167	170	173	169	181	181
16	155	162	158	165	157	140	151	149	146	142	145
13	124	129	112	121	125	92	95	110	112	106	112
15	146	149	150	151	145	117	134	133	127	132	133
5	57	50	51	54	57	40	40	47	42	42	40
4	36	41	43	39	40	29	36	34	33	36	36
84	87·1	88·5	84·9	87·8	85·3	83·8	88·8	86·1	86·4	78·5	80·1
85	84·9	86·6	74·6	80·1	86·2	78·6	70·9	82·7	88·2	80·3	84·2
73	63·2	82·0	84·3	72·2	70·1	72·5	90·0	72·3	78·6	85·7	90·0
42 5	41·8	44·6	44·5	43·6	44·6	41·3	43·6	47·2	45·2	45·0	45·7
01 5	—	103·5	105·8	100·2	103·7	99·5	102·1	109·8	105·0	102·1	104·6
52	53·0	52·2	52·5	52·8	51·5	56·2	55·1	52·8	54·3	52·9	50·6
22 5	23·4	23·0	23·9	21·8	19·7	22·3	20·2	21·6	22·6	20·1	19·9

er 5 and 10.

[14] Daughter of No. 68.

[15] Daughter of No. 38.

9a. Chilcotin.

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	I. Males																	
Name	Louis	Willie	Johnnie	Louis	Baptiste	Isidore	Michel	William	Leo	Tugan'n	Alexander	Timothy	Michel	Jerome	Tenache'z	Charlie	Atati'	Capt. Bobby
	[illegible]	[illegible]	[illegible]	[illegible]	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin
Observer	B	B	B	B	B	B.	B	B.	B.	F.	B	B	F	B.	B	F	F	B
Age	6	7	8	9	10	10	11	12	14	16	17	19	20	20	20	20	20	20
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height	1,101[1]	1,030[2]	1,266[3]	1,346	1,298[4]	1,302	1,383	1,276		1,654[5]	1,633	1,663[6]	1,553	1,730	1,722	1,706	1,677	1,633[8]
Id. shoulders	875	—	1,014	1,044	1,082	[illegible]	1,120	1,003		1,386	1,371	1,438	1,260	1,440	1,394	1,378	1,367	1,327
Length of arm	474		535	571	565	536	600	536	—	729	716	737	707	752	766	735	787	746
Finger reach	1,120	1,026	1,263	1,336	1,335	1,296	1,374	1,314	—	1,728	1,682	1,732	1,624	1,800	1,805	1,752	1,777	1,738
Height sitting	606	566		735	–	710	724	689	–	857	843	907	848	862	912	891	877	875
Width of shoulders	[illegible]		274	279	276	277	285	255		332	356	385	356	376	368	380	360	367
Length of head	[illegible]	158	172	176	178	167	175	169	176	190	190	181	187	192	192	188	184	185
Breadth of head	153	141	152	155	148	152	147	149	152	149.5	156	157	159	161	162	160	157	160
Height of face	101	96	104	103	104	111	104	98	103	119	110	130	123	126	109	137	115	130
Breadth of face	127	117	131	129	130	131	130	132	132	142	140	147	145	147	151	144	153	147
Height of nose	40	36	39	44	43	46	46	39	44	47	44	49	50	53	47	53	51	57
Breadth of nose	32	30	32	35	31	32	31	35	38	38	34	39	42	39	38	38	41	37
Length-breadth index	[illegible]	89.2	88.4	88.1	81.1	91.0	84.0	88.2	86.4	78.7	82.1	86.7	85.0	83.9	84.4	85.1	85.3	86.5
Facial index	79.5	82.1	79.4	79.8	80.0	84.7	80.0	74.2	78.0	83.8	78.6	88.4	84.8	85.7	72.2	95.1	75.2	88.4
Nasal index	80.0	83.3	82.1	79.6	72.1	69.6	67.4	89.8	86.4	80.8	77.3	79.6	84.0	73.6	80.8	71.7	80.4	64.9
Index of arm	43.1	—	42.4	42.3	43.5	41.2	43.5	41.9		44.2	43.9	45.6	45.6	43.5	44.5	43.0	46.8	45.7
Index of finger reach	101.7	99.6	99.8	99.3	102.9	99.5	99.3	103.0	—	104.5	103.0	105.4	104.6	104.0	104.8	102.7	106.0	106.4
Index of height sitting	55.1	55.0	—	54.4	-	54.6	52.5	53.8		51.9	51.7	54.5	54.7	49.8	53.0	52.1	52.2	53.7
Index of width of shoulders	22.8	—	21.6	20.6	21.2	21.3	20.7	19.9	—	20.1	21.8	23.2	22.9	21.7	21.4	22.3	21.4	22.5

Number	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Name	Jack	Johnnie	Charlie Boy	Sa'ma'n	Toby	Benny	William	Jim	Gilpan	Sam	Bob	Tommy	Tommy	Capt. Frank	Chapat	Quanil	Shimo	Jeff
	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin
Observer	F.	B	F	B	F	F	F	B	F	B.	B	F	B.	B.	F.	F	F	B.
Age	25	26	25	25	25	26	28	23	30	30	30	30	32	34	35	40	40	40
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height	1,746	1,820[9]	1,727	1,712	1,670	1,652	1,656	1,643	1,610	1,727[10]	1,670	1,634	1,770	1,628	1,555	1,679	1,677	1,643
Id. shoulders	1,444	1,605	1,426	1,124	1,379	1,340	1,378	1,363	1,317	1,425	1,360	1,311	1,445	1,343	1,271	1,378	1,380	1,370
Length of arm	789	775	755	712	737	710	723	743	704	747	812	714	809	679	690	782	735	740
Finger reach	1,832	1,848	1,826	1,774	1,733	1,657	1,724	1,805	1,688	1,763	1,751	1,698	1,846	1,665	1,607	1,806	1,747	1,733
Height sitting	867	949	912	—	868	892	825	870	877	—	871	872	894	885	850	851	891	803
Width of shoulders	398	420	372	376	366	370	325	372	394	396	375	391	370	357	348	351	385	338
Length of head	192	190	187	190	181	183	184	183	195	191	188	181	196	188	184	191	194	189
Breadth of head	163	160	157	153	155	156	150	158	164	166	161	158	159	166	156	156	155	163
Height of face	120	131	130	127	123	120	132	119	122	123	121	117	129	130	121	132	126	130
Breadth of face	150	154	151	147	145	144	143	147	148	153	152	153	148	154	137	155	147	149
Height of nose	56	56	55	49	49	55	55	57	51	62	55	49	54	56	50	55	52	52
Breadth of nose	38	41	38	38	36	39	41	39	38	48	42	43	40	39	34	41	37	37
Length-breadth index	84.9	84.2	84.0	80.5	85.6	85.2	81.5	86.3	84.1	86.9	85.6	87.1	81.0	88.3	84.8	81.7	79.9	86.2
Facial index	80.0	85.1	86.1	86.4	84.8	83.3	92.3	80.9	82.4	80.9	79.6	76.5	87.2	84.4	88.3	85.2	85.7	87.2
Nasal index	67.9	73.2	69.1	77.6	73.5	70.9	74.6	68.4	74.5	77.4	76.4	85.7	74.1	69.6	68.0	74.5	71.2	71.2
Index of arm	45.3	42.6	43.6	41.6	44.1	43.0	43.6	45.3	43.7	43.2	48.0	43.8	45.7	41.7	44.2	46.6	43.7	45.1
Index of finger reach	105.0	101.5	105.7	103.6	103.8	100.3	104.1	109.9	104.8	102.2	104.9	103.9	104.3	102.3	103.3	107.6	104.2	105.5
Index of height sitting	49.7	52.1	52.7	--	52.0	54.1	49.7	53.0	54.5	—	52.3	53.5	50.5	54.3	54.5	50.7	53.0	49.0
Index of width of shoulders	22.9	23.1	21.5	22.0	21.9	22.4	19.6	22.7	24.5	22.9	22.5	24.0	20.9	21.9	22.3	20.9	22.9	20.6

Number	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
													II. Females					
Name	Smiza	Charlie	Big John	Doctor	Captain	Little Johnnie	Jim	Quee'n	Chinaman	Dick	[illegible]	Charlie	Sallie	Suzanne	Emmaline	Minnie	Josephine	Lucy
	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin
Observer	B.	B.	B.	B.	B	F.	B.	F	F	B	F	F	B	B.	F	B	F	F
Age	45	45	45	45	50	60	60	55	55	55	55	55	6	9	11	12	13	20
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height	1,583	1,612[11]	1,667	1,665	1,558[13]	1,581	1,605	1,541	1,581	1,594	1,588	1,635	1,057	1,320[14]	1,370[15]	1,317	1,487	1,580
Id. shoulders	1,324	1,346	1,375	1,376	1,302	1,285	1,313	1,287	1,263	1,295	1,316	1,354	841	1,037	1,131	1,045	1,210	1,316
Length of arm	691	722	748	751	682	644	733	644	705	709	693	731	437	575	647	596	670	722
Finger reach	1,637	1,672	1,774	1,770	1,635	1,580	1,726	—	1,646	1,686	1,591	1,695	1,052	1,348	1,504	1,383	1,518	1,652
Height sitting	810	837	910	866	823	813	—	816	825	835	839	845	618	727	724	717	788	799
Width of shoulders	355	353	375	380	365	361	362	330	363	380	346	324	245	266	296	298	300	314
Length of head	189	181	186	180	179	185	182	178	183	186	168	184	167	170	173	169	181	181
Breadth of head	159	148	162	152	156	158	169	155	158	158	165	157	140	151	149	146	142	145
Height of face	123	131	126	121	125	120	124	124	129	112	121	125	99	95	110	112	106	112
Breadth of face	151	145	147	144	149	144	150	146	149	150	151	145	117	134	133	127	132	133
Height of nose	55	55	55	51	52	53	55	57	50	51	54	57	40	40	47	42	42	40
Breadth of nose	40	41	44	40	42	36	41	36	41	43	39	40	29	36	34	33	36	36
Length-breadth index	84.1	81.8	87.1	84.4	87.2	85.4	92.9	87.1	86.3	84.9	97.8	85.3	83.8	88.8	86.1	86.4	78.5	80.1
Facial index	81.5	90.3	85.7	84.0	83.9	83.3	82.6	84.9	86.6	74.6	80.1	86.2	84.6	70.9	82.7	88.2	80.3	84.2
Nasal index	72.7	74.5	80.0	78.4	80.7	67.9	74.5	63.2	82.0	84.3	72.2	70.1	72.5	90.0	72.3	78.6	85.7	90.0
Index of arm	43.7	44.8	44.8	45.0	43.7	40.8	45.6	41.8	44.6	44.5	43.6	44.6	41.3	43.6	47.2	45.2	45.0	45.7
Index of finger reach	103.4	103.7	106.4	106.3	104.9	100.0	107.5	—	103.7	105.8	100.2	103.7	99.5	102.1	109.8	105.0	102.1	104.6
Index of height sitting	51.3	51.9	54.5	51.9	52.8	51.4	—	53.0	52.2	52.6	52.8	51.6	58.5	55.1	52.8	54.3	52.9	50.6
Index of width of shoulders	22.5	21.9	22.5	22.8	23.4	22.8	22.5	21.4	23.0	23.9	21.8	19.7	23.2	20.2	21.6	22.6	20.1	19.9

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[1] Son of No 18.
[2] Son of No 20.
[3] Son of No 28.
[4] Son of No 48.
[5] Hunchback.
[6] Son of No. 48.
[7] Cousin of No 18.
[8] Father of No 1; cousin of No 12, son of Nos 41 and 67.
[9] Father of No 2.
[10] Father of No. 3.
[11] Father of No 51.
[12] Father of No 18.
[13] Father of Nos. 6 and 10.
[14] Daughter of No. 68.
[15] Daughter of No 38.

9b. *Chilcotin, Half-blood.* 10. *Carrier.*

				Male	Males				
Number .	73	74	75	76	1	2	3	4	5
Name .	Magdalen	Taraik	Atsekulá	George	Êzitô'l	Gᴇlē'	T'ēk·ᴇsē'a	Isaac	Jamie
Tribe .	Chilcotin	Chilcotin	Chilcotin	F. American M. Chilcotin	Ntcat'i'n	Ntcat'i'n	F. Têslatat'i'n M. Ntcat'i'n	Alexandria	F. Alexandria (full ?) M. ½ Carrier, ½ White
Observer .	F.	B.	B.	B.	B.	B.	B.	F.	B.
Age .	70	70	75	12	17	18	50	55	13
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standin	1,548	—	—	1,495	1,685	1,654	1,775	1,535	1,423
Height of shou	1,288	--	—	1,192	1,364	1,328	1,477	1,265	1,170
Length of arm	710	—	—	658	751	725	717	700	658
Finger-reach .	1,624	—	—	1,577	1,757	1,702	1,705	1,647	1,495
Height sitting	818	—	—	763	855	862	931	775	765
Width of shoul	330	—	—	339	373	363	374	355	248
Length of head	171	169	175	185	190	185	196	179	180
Breadth of hea	154	149	149	151	164	156	160	153	159
Height of face	114	127	106	107	129	121	141	130	112
Breadth of face	143	140	136	136	152	146	155	140	131
Height of nose	54	58	53	47	59	51	58	53	44
Breadth of nose	36	39	39	35	36	37	39	37	32
Length-breadth	90·1	88·2	85·1	81·6	86·3	84·3	81·6	85·5	88·3
Facial index .	79·7	90·7	77·9	78·7	84·9	82·9	91·0	92·8	85·5
Nasal index .	66·7	67·2	73·6	74·5	61·0	72·5	67·2	69·8	72·7
Index of arm .	45·8	—	—	44·2	44·7	43·9	40 3	45·5	46·3
Index of finger-	104·9	—	—	105·5	104·3	102·9	96·1	107·3	105·1
Index of height	52·8	—	—	51·2	50·9	52·2	52·3	50·3	53·9
Index of width	21·3	—	—	22·8	22·2	22·0	21·0	23·1	17·5

Mother of No. 61.

	9a. *Chilcotin* (continued)																					9b. *Chilcotin, Halfblood.*	10. *Carrier*				
	Females (*continued*)																					Male	Males				
Number	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	1	2	3	4	5
Name	[illegible]	[illegible]	Lucy	[illegible]	[illegible]	[illegible]	Minnie	Nancy	Susanne	Nellie	Mary	Betsy	Christine	[illegible]	Lucy	Lucy	[illegible]	Sally	Magdalena	[illegible]	Aleck	George	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Chilcotin	[illegible]	Chilcotin	[illegible]	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	Chilcotin	F. [illegible] M. Chilcotin	[illegible]	[illegible]	F. [illegible] M. [illegible]	Alexandria	F. Alexandria (full) M. [illegible]
[illegible]	F	[illegible]	B	F	B.	B	B.	F.	B	B.	B	B	F	B	B	B	B	B	F.	B	B	B	B	B	B	F	B
[illegible]	[illegible]	22	25	25	26	30	30	30	35	38	45	47	55	55	58	60	65	65	70	70	75	12	17	18	50	55	[illegible]
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
[illegible]	[illegible]	[illegible]	1,556	1,604	1,575[18]	1,602	1,582[17]	1,571	1,508	1,550	1,557	1,549	1,527[19]		* 1,560[20]	1,543	1,540	1,509	1,515			1,495	1,685	1,651	1,775	1,535	1,124
[illegible]	1,257	1,322	1,281	1,364	1,303	1,306	1,304	1,294	1,228	1,281	1,308	1,264	1,273		1,255	1,264	1,293	1,221	1,285	—		1,192	1,364	1,328	1,477	1,265	1,170
Length of arm	694	743	655	756	733	690	691	680	657	683	661	681	674	—	655	692	716	697	710		—	658	751	725	717	700	658
Finger reach	1,590	1,718	1,560	1,618	1,679	1,685	1,609	1,567	1,524	1,639	1,616	1,592	1,586		1,676	1,644	1,632	1,545	1,624	—		1,577	1,757	1,702	1,705	1,617	[illegible]
Height sitting		864	855	846	852	811	832	846	784	799	813	799	780	—	785	823	778	787	818	—		763	856	862	931	[illegible]	[illegible]
Width of shoulders	316	337	[illegible]	352	326	343	373	346	337	362	340	317	350	—	336	346	308	[illegible]	330	—		339	[illegible]	363	[illegible]	[illegible]	[illegible]
Length of head	182	186	179	180	171	176	172	180	183	184	174	171	178	172	183	184	172	176	171	169	175	185	190	185	196	179	180
Breadth of head	163	150	152	149	146	146	162	157	155	161	157	153	151	166	160	157	154	155	154	149	149	151	164	156	160	153	159
Height of face	110	113	108	114	114	117	120	116	114	131	118	116	123	109	117	122	111	129	114	127	106	107	129	121	141	130	112
Breadth of face	160	145	139	138	134	141	146	139	143	148	141	135	139	142	117	144	139	144	143	140	136	136	164	146	155	140	131
Height of nose	49	44	43	45	49	49	56	39	51	51	51	46	52	50	54	53	51	58	54	58	53	47	59	51	58	53	44
Breadth of nose	36	36	37	35	38	30	38	37	36	41	35	32	34	37	40	39	37	37	36	39	39	35	36	37	39	37	32
Length-breadth index	89.6	80.6	84.9	82.8	85.4	83.0	94.2	87.2	84.7	87.5	90.2	89.5	86.0	91.7	87.4	85.3	89.5	88.1	90.1	88.2	85.1	81.6	86.3	84.3	81.6	85.5	88.3
[illegible] index	[illegible]	77.9	77.7	82.6	85.1	83.0	82.2	83.5	79.7	88.5	83.7	85.9	88.5	76.8	[illegible]	84.7	79.9	89.6	79.7	90.7	77.9	78.7	[illegible]	82.9	91.0	92.8	85.5
Nasal index	73.5	81.8	86.0	77.8	77.6	61.2	67.9	94.9	70.5	80.4	68.6	69.6	65.4	74.0	74.1	73.6	72.5	63.8	66.7	67.2	71.6	74.5	61.0	72.5	67.2	69.8	72.7
[illegible] arm	44.5	45.2	42.1	47.3	46.4	43.1	43.7	43.3	43.5	44.1	42.8	44.2	44.1		42.0	[illegible]	46.5	[illegible]	45.8	—		44.2	44.7	[illegible]	[illegible]	45.5	[illegible]
Index of finger reach	102.8	106.0	100.3	100.9	106.6	102.1	101.7	99.7	101.1	105.7	[illegible]	103.2	103.9	—	101.0	106.6	106.0	[illegible]	104.9		—	105.5	104.3	[illegible]	96.1	107.4	105.4
Index of height sitting		[illegible]	55.0	52.9	53.9	50.7	[illegible]	53.2	51.9	51.5	62.5	51.9	51.0		50.3	53.4	50.5	52.5	52.8	-		51.2	50.5	52.2	[illegible]	50.3	63.9
Index of width of shoulders	22.5	20.8	21.5	20.7	20.6	21.4	23.6	22.0	22.3	23.4	21.9	20.6	22.9	—	21.5	22.4	20.0	21.7	21.3	—	—	22.8	22.2	22.0	21.0	28.1	17.5

* Partly mixed with Carrier. [17] Daughter of No. 69. [18] Mother of No. 18. [19] Mother of No. 50. [20] Mother of No. 61.

	ımtcī'nEmuQ ed with ısıcap.	*11i. Half-blood Ntlakya'pamuQ.*			*13. Okanagan.*			*13a. Okanagan half-blood.*
	Man	Males		Female	Males		Female	Male
Num	14	1	2	3	1	2	3	1
Nam	TuzlExeskt	Georgie	Felix	Theresa	Daniel Celestin	Edward Moreno	Julienne	Simon
Tribe	M. { 3/4 Nkamtcī'nEmuQ 1/4 Shuswap	F. ? M. Utā'mqt	F. ? M. Utā'mqt	—	Okanagan	Okanagan	F. Nicola M. Okanagan	½ Okanagan
Obse	B.	F.	B.	B.	F.	B.	B.	F.
Age	30	15	15	14	11	14	13	12
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Heig	1,674	1,412	1,393	1,402	1,292	1,442	1,554	1,432
Heig	1,364	1,142	1,112	1,127	1,024	1,142	1,256	1,172
Leng	737	609	619	599	564	602	684	634
Fing	1,748	1,475	1,434	1,433	1,323	1,452	1,622	1,446
Heig	893	724	746	739	683	783	836	726
Widt	398	321	320	316	285	296	362	310
Leng	188	186	180	155	183	188	179	176
Bread	158	153	151	143	150	146	155	146
Heig	119	107	101	99	100	115	110	95
Bread	143	132	133	127	128	127	141	129
Heig	49	43	45	41	42	47	41	43
Bread	36	33	34	29	31	39	32	31
Leng	84·0	82·3	83·9	92·3	82·0	77·7	86·6	83·0
Facia	83·2	81·1	78·2	78·0	78·1	90·6	78·0	73·6
Nasal	73·5	76·7	75·6	70·7	73·8	83·0	72·7	72·1
Index	44·1	43·2	44·5	42·8	43·7	41·8	44·1	44·3
Index	104·4	104·5	102·9	102·2	102·4	100·7	104·4	101·0
Index	53·5	51·3	53·7	52·8	52·9	54·4	53·9	50·8
Index	23·8	22·8	23·0	22·6	22·1	20·6	23·4	21·7

	11c. [illegible]			11d. Utā'mqt and [illegible]		11e. Ntlakyapamuq'ō'e.	11f. Ntlakyapamuq'ō'e and other tribes mixed.						11g. Nkamtcinemux	11h. Nkamtcinemux mixed with Shu[illegible]	11i. Half-blood Ntlakyapamuq			13. Okanagan			13a. Okanagan half-blood.
	M[illegible]		Female	[illegible]		Female	Males		Females				Male		Males		Female[1]	Males		Female	Male
Number	1	2	3	4	5	6	7	8	9	10	11	12	1	11	1	2	3	1	2	3	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Edward M[illegible]	J[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	Ntlakyapamuq	M. Lytton	[illegible]	[illegible]	F. Lytton M. N[illegible]	[illegible]	[illegible]	Nkamtcinemux	[illegible]	M. [illegible]	M. [illegible]		Okanagan	Okanagan	F. Nic[illegible] M. Okanagan	Okanagan
Observer	F	F	F	B	B	F	B	B	B	B	B	F	[illegible]	[illegible]	F	B	B	F	B.	B.	F
Age	11	15	12	60	65+	25	15	65	35	40	50	6[illegible]	60		15	15	14	11	14	13	12
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	1,40[illegible]	1,462	1,410	1,460[1]	[2]	1,540	1,677	1,693	1,673	1,640	1,560	1,467	1,670	1,5[illegible]4	1,512	1,[illegible]	1,402	1,292	1,442	1,554	1,432
Height of shoulder	1,157	1,11[illegible]	1,117	1,205	—	1,278	1,390	1,323	1,262	1,278	1,273	1,185	1,418	1,[illegible]41	1,112	1,112	1,127	1,021	1,142	1,256	1,172
Length of arm	5[illegible]	619	595	632	[illegible]	707	765	728	690	688	668	624	811	[illegible]	609	6[illegible]	[illegible]	[illegible]64	602	681	631
Finger reach	1,41[illegible]	1,465	1,397	1,402	[illegible]	1,628	1,733	1,710	1,610	1,600	1,563	1,[illegible]	1,850	1,[illegible]	1,175	[illegible]	1,[illegible]	1,[illegible]	1,472	1,622	1,446
Height sitting	723	73[illegible]	765	755	[illegible]	763	—	830		—	814	786		[illegible]	724	716	7[illegible]	68[illegible]	78[illegible]	[illegible]	726
Width of shoulders	333	323	307	306		340	375	392	348	338	350	[illegible]	[illegible]	[illegible]	[illegible]21	[illegible]20	31[illegible]	28[illegible]	29[illegible]	[illegible]	310
Length of head	177	177	173	185	192	174	182	188	184	173	17[illegible]	[illegible]	18[illegible]	[illegible]	186	180	1[illegible]	15[illegible]	188	170	176
Breadth of head	152	156	151	145	148	[illegible]	152	151	151	146	147	[illegible]	[illegible]	[illegible]	153	15[illegible]	[illegible]	150	146	[illegible]	146
Height of face	[illegible]	101	101	112	120	108	117	121	111	117	122	[illegible]7	106	11[illegible]	107	[illegible]	[illegible]	1[illegible]0	115	110	[illegible]
Breadth of face	[illegible]	11[illegible]	130	137	142	133	113	148	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]2	[illegible]	127	[illegible]	127	141	123
Height of nose	[illegible]	[illegible]	[illegible]	52	59	49	49	61	53	[illegible]0	[illegible]	[illegible]	48	[illegible]	[illegible]	[illegible]	41	42	47	44	[illegible]
Breadth of nose	37	37	32	37	47	31	41	40	34	[illegible]	[illegible]1	[illegible]7	37	[illegible]	33	[illegible]1	29	[illegible]1	39	32	[illegible]1
Length-breadth index	85.9	88.1	87.3	78.4	77.1	86.1	83.5	80.3	82.1	84.4	[illegible]	[illegible]	82.1	[illegible]	82.3	83.9	92.3	82.0	77.7	86.6	87.0
Facial index	[illegible]	[illegible]	80.0	81.8	84.5	81.2	81.8	81.7	81.1	86.0	89.7	86.0	70.7	81.2	81.1	78.2	78.0	78.1	90.6	78.0	73.6
Nasal index	[illegible]	[illegible]	71.1	71.2	63.8	70.8	83.7	65.6	64.2	64.0	65.1	75.5	77.1	73.5	76.7	75.6	70.7	71.8	83.0	72.7	72.1
Index of length of arm	42.[illegible]	44.2	42.2	43.3	—	45.9	45.6	45.8	41.9	44.7	42.2	42.4	48.7	44.1	43.2	44.5	42.8	43.7	41.8	44.1	41.3
Index of finger reach	102.9	104.5	99.1	102.2	—	105.7	103.3	107.4	102.4	103.0	100.2	100.3	110.8	[illegible]	101.5	102.9	102.2	102.1	100.7	104.4	101.0
Index of height sitting	51.6	52.2	54.3	51.7	—	49.7	—	52.2	—	—	54.1	53.5		[illegible]5.5	51.3	53.7	52.8	52.0	54.4	55.9	50.8
Index of width of shoulders	23.8	23.1	21.8	21.0	—	22.1	22.3	24.0	22.2	21.9	22.4	21.9	23.1	23.8	22.8	23.0	22.6	22.1	20.6	23.4	21.7

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[1] Sister of No. 5

[2] Sister of No. 4

18. *Hēiltsuk.*

			II. Females						Half-breed
6	7	8	9	10	11	12	13	14	15
Waqait	Malaqns	Nōnōqns	Nellie Watson	Sakwē'	Susan	Ida	Alakamilq	Jenny	Harry
Bella Bella	Bella Bella	F. Istaitq M. Bella Bella	Bella Bella	Istaitq	Istaitq	Istaitq	—	Istaitq	M. Bella Bella
F.	F.	F.	F.	F.	F.	F.	F.	F.	F.
55	60	70	20	25	40	50	55	60	35
mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1,607	1,568	1,623	1,574	1,414	1,533	1,465	—	1,443	1,613
1,321	1,285	1,326	1,301	1,158	1,265	1,210	—	1,181	1,305
725	754	743	718	633	633	640	—	667	733
1,701	1,780	1,774	1,654	1,486	1,528	1,543	—	1,535	1,723
811	—	—	810	—	838	755	—	—	—
376	398	358	375	332	351	360	—	—	393
181	185	190	185	181	179	181	184	186	185
168	170	170	155	153	162	155	167	157	156
117	126	127	112	120	123	113	118	114	124
154	163	159	146	141	155	152	148	150	143
51	58	52	45	50	52	48	49	47	52
41	47	42	37	—	40	38	43	40	33
92·8	91·9	89·5	83·8	84·5	90·5	85·6	90·8	84·4	84·3
76·0	77·3	79·9	76·7	85·1	79·4	74·3	79·7	76·0	86·7
80·4	81·0	80·8	82·2	—	76·9	79·2	87·8	85·1	63·5
45·0	48·0	45·9	45·7	44·9	41·4	43·5	—	46·3	45·5
105·8	114·2	109·3	105·1	105·1	99·7	105·3	—	106·4	106·8
50·4	—	—	51·6	—	54·8	51·4	—	—	—
23·4	25·4	22·1	23·9	23·5	22·9	24·5	—	—	24·4

	12. *Tlingit.*		13. *Haida.*														
	Full-blood	Half-blood	I. Males									II. Females					
Number	1	2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name	Anne McKay	G. H.	Guy	Guy Ts'a'lat	John Smith qo'ngola	Wash'n (?) Atkö'rg	Samuel	Herbert Nängä'la	John Robinson Gasqläns	Joshua Moody Gala	Stevens Edison Nuwä'it	Emily	Mary	Susie	Louisa	Ruth Edensha'n	Mary
	[illegible]	F. English, M. Tlingit	Masset	Masset	Masset	Kaigani	Masset	Masset	Skidegate	F. Kaigani, M. Masset	Skidegate	F. Masset, M. Skidegate	Masset	Masset	Masset	Masset	Skidegate
Observer	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.
Age	28	45	13	14	19	21	30	32	40	40	40	13	14	18	18	28	35
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,506	1,741	1,472	1,463	1,654	1,668	1,624	1,610	1,685	1,564	1,542	1,603	1,462	1,590	1,528	1,550	1,530
Height of shoulder	[illegible]	1,4[illegible]0	1,2[illegible]	1,190	1,365	1,362	1,291	1,3[illegible]6	1,360	1,291	1,243	1,230	1,181	1,318	1,232	1,246	—
Length of arm	657	765	[illegible]	632	718	757	721	728	730	719	680	650	613	711	632	653	[illegible]
Finger reach	1,555	1,810	1,48[illegible]	1,486	1,700	1,798	1,723	1,7[illegible]2	1,800	1,66[illegible]	1,6[illegible]	1,553	1,561	1,631	1,7[illegible]1	1,654	1,760
Height sitting	847	945	800	793	923	890	890	91[illegible]	[illegible]	818	881	762	792	828	810	826	835
Width of shoulders	359	425	328	329	382	410	405	387	425	356	398	352	307	356	316	321	—
Length of head	179	191	168	188	189	193	196	207	199	190	189	187	188	176	186	185	181
Breadth of head	151	170	161	151	163	169	[illegible]	164	160	171	158	155	152	147	153	156	148
Height of face	124	1[illegible]3	114	121	120	120	115	[illegible]	[illegible]	121	121	[illegible]	[illegible]	111	[illegible]	118	[illegible]
Breadth of face	[illegible]	155	138	137	149	156	[illegible]	151	152	158	153	138	[illegible]	140	142	118	[illegible]
Height of nose	51	[illegible]	44	42	[illegible]	50	48	[illegible]	55	49	48	48	[illegible]	46	46	[illegible]	45
Breadth of nose	35	39	33	35	39	43	40	39	47	39	40	33	33	35	31	36	38
Length-breadth index	84·4	89·0	80·3	80·3	86·2	87·6	86·7	79·3	80·4	90·0	83·6	82·9	80·5	83·5	82·3	84·[illegible]	81·8
Facial index	80·9	85·8	82·6	81·0	80·5	76·9	74·2	85·1	86·2	76·6	84·0	84·8	84·1	80·7	83·9	79·7	81·3
Nasal index	68·6	66·1	75·0	83·3	75·0	86·0	83·3	70·9	85·5	79·6	83·3	66·8	71·7	76·1	73·9	69·2	84·4
Index of arm	43·6	44·0	44·6	43·3	43·6	45·3	44·5	44·4		46·1	44·2	43·3	42·0	44·8	—	40·8	
Index of finger-reach	103·2	104·0	100·8	101·6	102·8	107·8	106·1	105·6	106·8	106·3	107·5	103·3	102·7	102·6	100·2	100·3	10[illegible]·7
Index of length sitting	56·1	54·3	54·4	54·3	55·9	53·3	55·5	55·7	54·2	52·4	57·1	50·8	54·2	52·1	52·9	53·3	51·9
Index of width of shoulders	23·8	24·4	22·3	22·5	23·2	24·6	24·9	23·6	25·3	22·8	25·8	22·1	21·0	22·4	22·6	20·7	—

	14. *Tsimshian.*					15. *Gyitkshan.*									
	I. Males		II. Females			Males									
Number	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10
Name	Joshua McKay	David Start	Cecilia McKenzie	Jane Bernard	Ida Greene	Benjamin Peter Brown	Peter John Tlipland'alsq	Richard Dawse	Arthur Wilson	Lazarus Brown Iola'sku	Albert Dawse	Boston	Charlie Lale	Mark Green	Jack Welsh
	F. Ts'ts'[illegible], M. Gyitsala's	F. Gyitsala's, M. Gyitsemga'l'on	F. Gyitsala's, M. Gyitsemga'l'on	F. Gyitsala's, M. Gyispaqlo'ts	Gyitsala's	F. Nisk·a', M. Gyitspayo'ks	Gyitspayo'ks	F. Gyit'anma'kys, M. Gyitwuntlgo'l	Gyits'yo'ktla	Gyitspayo'ks	Gyitwuntlgo'l	Gyitspayo'ks	Gyitsgega'la	Gyitspayo'ks	Gyitwuntlgo'l
Observer	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.	B.
Age	21	23	20	45	50	22	24	23	26	27	32	15	45	18	50
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,750	1,73[illegible]	1,494	1,615	1,563	1,625	1,629	1,680	1,727	1,616	1,617	1,7[illegible]2	1,5[illegible]7	1,660	1,652
Height of shoulder	1,443	1,417	1,201	1,220	1,268	1,333	1,297	1,363		1,298	1,3[illegible]	1,42[illegible]	1,302	1,371	1,310
Length of arm	764	78[illegible]	623	668	686	780	687	719		710	751	775	684	773	718
Finger reach	1,810	1,8[illegible]	1,[illegible]45	1,611	1,[illegible]48	1,767	1,677	1,72[illegible]	1,8[illegible]	1,730	1,7[illegible]2	1,775	1,657	1,528	1,686
Height sitting	921	91[illegible]	8[illegible]8	818	826	817	692	891	953	870	890	890	827	878	9[illegible]5
Width of shoulders	396	381	336	347	369	359	373	375	410	377	3[illegible]9	311	364	4[illegible]7	371
Length of head	187	19[illegible]	182	190	187	192	185	190	190	193	18[illegible]	[illegible]	199	194	193
Breadth of head	167	[illegible]	[illegible]	165	15[illegible]	156	157	164	160	154	159	160	155	156	143
Height of face	127	[illegible]	118	[illegible]	121	[illegible]	118	[illegible]	111	128	120	119	122	121	114
Breadth of face	150	[illegible]	[illegible]	148	[illegible]	150	110	[illegible]	170	148	[illegible]	155	119	171	145
Height of nose	[illegible]	[illegible]	49	51	50	57	[illegible]	50	47	[illegible]	50	[illegible]	58	60	55
Breadth of nose	44	41	34	30	42	39	41	37	38	—	41	39	41	42	40
Length-breadth index	[illegible]	81·4	81·9	81·6	8[illegible]·1	81·2	81·[illegible]	86·[illegible]	81·2	79·8	81·1	80·8	76·0	80·4	74·1
Facial index	81·7	82·1	86·1	77·7	82·9	87·3	79·2	74·0	76·0	86·5	80·5	71·8	81·9	81·0	77·9
Nasal index	78·6	75·9	69·4	76·5	84·0	68·4	80·1	71·0	80·9	—	82·0	78·0	70·7	81·0	72·7
Index of arm	43·7	4[illegible]·1	45·8	44·2	44·1	47·9	42·1	42·8	—	43·8	45·5	44·8	42·5	46·6	44·0
Index of finger-reach	103·4	104·0	103·4	105·5	104·8	108·6	103·0	105·5	106·0	107·0	105·2	104·9	104·3	111·1	103·8
Index of length sitting	52·8	5[illegible]	54·2	54·2	53·0	50·1	54·7	53·2	55·1	53·7	53·9	51·4	51·4	52·9	55·5
Index of width of shoulders	22·6	22·0	22·6	23·0	23·7	22·0	22·0	22·3	23·7	23·3	22·4	19·7	22·0	28·1	21·7

	16. *Nisk·a.*		17. *Inlyulo.*		
	Males		I. Males		II. Female
Number	1	2	1	2	3
Name	Sam Williams	Joseph Ford Latimer	Thomas	Sam	Sadie
	Nisk·a'	F. Ts'ts'[illegible], M. Nisk·a'	Sats'aniq	Sats'aniq	Sats'aniq
Observer	B.	B.	F.	F.	F.
Age	20	28	50	30	30
	mm.	mm.	mm.	mm.	mm.
Height standing	1,720	1,6[illegible]9	1,598	1,679	1,608
Height of shoulder	1,405	1,304	1,[illegible]50	1,388	1,321
Length of arm	738	741	7[illegible]8	784	761
Finger reach	1,773	1,764	1,774	1,816	1,677
Height sitting	922	927	884	855	—
Width of shoulders	366	388	422	425	372
Length of head	182	203	189	191	191
Breadth of head	159	157	166	158	159
Height of face	119	125	130	124	121
Breadth of face	113	131	1[illegible]2	1[illegible]5	116
Height of nose	48	49	52	53	49
Breadth of nose	36	38	38	41	35
Length-breadth index	87·4	77·3	8[illegible]·3	82·7	83·2
Facial index	8[illegible]·2	81·6	85·5	80·0	84·9
Nasal index	75·0	77·6	71·1	77·4	71·1
Index of arm	44·1	45·5	43·4	46·7	49·5
Index of finger-reach	103·1	108·3	101·5	108·2	104·3
Index of length sitting	53·6	66·9	62·0	50·9	
Index of width of shoulders	21·3	23·8	24·8	25·3	23·1

	18. *Heiltsuk.*														
	I. Males					II. Females									Half-breed
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name	Moapala	Joe	Charlie	Sam	Tsaqola	Wa[illegible]alt	Mala[illegible]	N[illegible]ep	Nellie W[illegible]	[illegible]	[illegible]	[illegible]	Alakam	Jenn[illegible]	[illegible]
	Bella Bella	Islaitq	Bella Bella	Bella Bella	Bella Bella	Bella Bella	Bella Bella	F. Islaitq, M. Bella Bella	Bella Bella	Islaitq	Islaitq	Islaitq		Islaitq	M. Bella Bella
Observer	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	[illegible]
Age	19	10	50	60	65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		60	[illegible]
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Height standing	1,412	1,576	1,725	1,650	1,637	1,607	1,7[illegible]8	1,6[illegible]	1,7[illegible]4	1,[illegible]	[illegible]	1,[illegible]65		1,4[illegible]	1,513
Height of shoulder	1,1[illegible]5	1,373	1,417	1,354	1,332	[illegible]	1,[illegible]55	[illegible]	1,[illegible]01	[illegible]	[illegible]	1,210		1,181	1,2[illegible]5
Length of arm	605	747	791	7[illegible]9	746	72[illegible]	77[illegible]	742	71[illegible]	[illegible]	[illegible]	[illegible]10		[illegible]67	73[illegible]
Finger reach	1,470	1,784	1,825	1,721	1,722	1,7[illegible]1	1,780	1,774	[illegible]	1,[illegible]86	[illegible]	1,[illegible]13		1,[illegible]5	1,7[illegible]
Height sitting	—	—	913	844	868	811			811		[illegible]	775			
Width of shoulders	315	400	301	398	381	37[illegible]	[illegible]	[illegible]	375	312	[illegible]51	360			[illegible]
Length of head	181	190	180	188	183	[illegible]	[illegible]	190	185	181	179	181	181	186	187
Breadth of head	162	167	167	170	159	[illegible]68	170	170	[illegible]	[illegible]	162	155	167	177	[illegible]
Height of face	[illegible]	129	115	131	124	[illegible]	[illegible]	127	[illegible]	120	12[illegible]	111	118	111	12[illegible]
Breadth of face	111	152	151	162	152	[illegible]	[illegible]	[illegible]	[illegible]	141	155	152	[illegible]	150	[illegible]13
Height of nose	42	51	51	54	51	[illegible]	[illegible]	[illegible]		[illegible]	52	48	[illegible]	47	[illegible]
Breadth of nose	35	42	43	43	41	41	47	42	37	—	40	38	44	40	35
Length-breadth index	85·0	87·9	92·8	90·4	86·9	[illegible]·8	[illegible]	89·5	[illegible]·8	81·5	90·5	85·6	90·8	94·4	81·[illegible]
Facial index	78·0	84·9	75·2	80·0	81·6	76·0	77·5	73·[illegible]	76·7	8[illegible]·1	7[illegible]·1	71·3	71·7	70·0	86·7
Nasal index	83·3	82·4	84·1	86·[illegible]	83·0	[illegible]·4	81·[illegible]	80·8	82·2		76·[illegible]	79·2	87·8	87·1	6[illegible]
Index of arm	42·9	43·9	46·0	46·6	45·5	45·0	48·0	45·[illegible]	45·7	44·0	41·4	43·6		46·3	45·5
Index of finger-reach	102·7	106·4	105·8	101·3	105·2	105·6	111·2	100·3	105·1	106·1	99·7	105·[illegible]	—	106·1	106·8
Index of length sitting	—	—	54·2	51·2	52·9	5[illegible]			51·6	—	51·8	51·4	—		—
Index of width of shoulders	22·3	23·8	17·5	24·1	23·2	23·4	25·1	22·1	23·9	23·5	22·9	2[illegible]			21·[illegible]

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[1] Height of point of second finger 610.

[2] Son of Nos. 6 and 14.

[3] Father of No. 2.

[4] Mother of No. 2.

[5] Brother of No. 6.

[6] Brother of N

20. *Kwakiutl Men.*

	nales								
Number .	17	18	19	20	21	22	1	2	3
Name .	G·uē'kyēlakwa	Tlā'k·oagyi-layuk·oa	Tl'ā'k·oask·Em	Hē'lēistēsEla	Ha'mlitl	K·oē'Hak·as	G·ō'lsElas	Pō'tlas	NE'msk·Emalîs
Tribe .	Awī'ky'ēnôq	Awī'ky'ēnôq	Awī'ky'ēnôq	F. $\frac{1}{2}$ Sō'nqulitq, $\frac{1}{2}$ Kwa-kiutl. M. Awī'ky'ēnôq	Awī'ky'ēnôq	F. Awī'ky'ēnôq. M. $\frac{1}{2}$ Hē'iltsuk·, $\frac{1}{2}$ Awī'ky'ēnôq	F. Kwakiutl M. Tena'qtaq	F. Kwakiutl M. Tena'qtaq	F. Tena'qtaq M. Awaitlala
Observer .	B.	B.	B.	B.	B.	B.	B.	B.	B.
Age .	35	40	40	40	52	60	35	45	40
	mm.	mm.	mm.	mm	mm.	mm.	mm.	mm.	mm.
Height standin	,528 [8]	1,457	1,492	1,508	1,544	1,462	1,540 [9]	1,610 [10]	1,670
Height of shoul	,244	1,192	1,222	1,223	1,254	1,203	1,242	1,310	1,357
Length of arm	647	619	669	617	692	679	672	745	764
Finger-reach .	,588	1,505	1,551	1,482	1,634	1,558	1,604	1,727	1,793
Height sitting	865	762	800	828	808	784	863	843	806
Width of shoul	367	343	308	356	343	340	369	378	390
Length of head	183 [2]	166 [2]	161 [2]	169 [7]	176 [2]	183 [2]	184 [2]	189 [2]	205 [2]
Breadth of hea	154 [2]	146 [2]	153 [2]	144 [7]	155 [2]	160 [2]	155 [2]	161 [2]	157 [2]
Height of face	118	116	114	118	120	119	124	135	130
Breadth of face	149	141	138	147	153	150	139	147	157
Height of nose	50	45	49	49	52	54	56	58	53
Breadth of nos	35	36	35	35	38	36	37	36	42
Length-breadt	84·2 [2]	88·0 [2]	95·0 [2]	85·2 [7]	88·1 [2]	87·4 [2]	84·2 [2]	85·2 [2]	76·6 [2]
Facial index .	79·2	82·3	82·6	80·3	78·4	79·3	89·2	91·8	82·8
Nasal index .	70·0	80·0	71·4	71·4	73·1	66·7	66·1	62·1	79·2
Index of arm .	42·3	42·4	44·9	40·9	44·9	46·5	43·6	46·3	45·7
Index of finger	03·9	103·3	104·0	98·3	105·8	106·6	104·2	107·3	107·4
Index of height	56·5	52·2	53·7	54·8	52·5	53·7	56·0	52·4?	48·3
Index of width	24·0	23 5	20·7	23·6	22·3	23·3	24·0	23·5	23·4

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[1] Slightly de [6] Daughter of Nos. 6, 17. [7] Head flattened behind.

19. *Awī'ky'ēnôx.*

20. *Kwakiutl Men.*

	I. Males															II. Females									
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Name	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tribe	Awī'ky'ēnôx	Awī'ky'ēnôx	Awī'ky'ēnôx	Awī'ky'ēnôx	Awī'ky'ēnôx	[illegible]	Awī'ky'ēnôx	Awī'ky'ēnôx	[illegible]	Awī'ky'ēnôx	[illegible]	[illegible]	Awī'ky'ēnôx	[illegible]	[illegible]	Awī'ky'ēnôx	Awī'ky'ēnôx	Awī'ky'ēnôx	Awī'ky'ēnôx	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	B	B	B	F	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	F	[illegible]
Age	14	20	28	30	35	40	50	55	60	65	37	20	20	21	30	30	35	40	10	40	52	60	25	45	40
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Height standing	1,560	1,666	1,631	1,617[4]	1,613	1,577[4]	1,593	1,500	1,663	1,624	1,532[4]	1,520	1,513	1,502	1,572	1,520	1,528[4]	1,467	1,492	1,508	1,541	1,462	1,540[4]	1,610[10]	1,670
Height of shoulder	1,256	1,367	1,304	1,301	1,307	1,293	1,277	1,197	1,345	1,316	1,248	1,240	1,240	1,214	1,304	1,251	1,244	1,192	1,222	1,224	1,254	1,203	1,242	1,310	1,367
Length of arm	673	709	704	775	689	718	701	627	703	744	681	650	640	629	682	676	647	619	669	617	642	679	672	746	764
Finger reach	1,598	1,688	1,714	1,780	1,682	1,646	1,746	1,593	1,695	1,764	1,608	1,538	1,560	1,520	1,591	1,632	1,588	1,515	1,551	1,482	1,631	1,558	1,604	1,727	1,793
Height sitting	847	916	913	826	893	857	831	846	893	856	840	829	844	834	837	843	865	762	800	828	809	781	863	843	806
Width of shoulders	334	348	380	395	375	375	399	359	371	338	328	323	347	340	326	351	367	346	308	356	343	340	369	378	390
Length of head	179	189	184[1]	190	186[2]	196[2]	185	180[2]	181[2]	192[2]	176	170	176	169[7]	182[8]	180[2]	183[2]	166[2]	161[2]	167	176[3]	163[2]	184[3]	189[2]	205[2]
Breadth of head	149	159	158[1]	154	157[2]	150[2]	158	161[2]	149	157[2]	156	152	150	163[7]	151[8]	159[2]	154[2]	146[2]	153[2]	144[2]	155[3]	160[2]	155[3]	161[2]	157[2]
Height of face	114	126	123	135	134	131	115	128	115	134	111	116	108	113	126	116	118	110	114	118	120	119	124	135	130
Breadth of face	138	147	147	152	153	155	156	154	148	156	140	138	142	139	145	148	149	141	138	147	153	150	139	147	157
Height of nose	46	54	47	56	57	56	53	56	50	57	49	47	40	53	56	51	50	45	49	49	52	54	56	58	53
Breadth of nose	37	37	36	41	40	41	40	43	38	40	33	35	35	31	35	37	35	36	35	35	38	36	37	36	42
Length-breadth index	83.2	84.1	85.9[1]	81.1	84.4[2]	76.6[2]	85.4	89.4[2]	82.3[2]	81.8[2]	88.6	89.4	85.2	96.4	83.0[8]	88.3[2]	84.2[2]	88.0[2]	95.0[2]	86.2[2]	88.1[3]	97.4[2]	84.2[3]	85.2[3]	76.6[2]
Facial index	82.6	85.7	83.7	88.8	87.6	84.5	73.7	83.1	77.7	85.9	79.3	83.9	76.1	81.3	86.9	77.7	79.2	82.1	82.6	80.3	78.4	79.3	89.2	91.8	82.8
Nasal index	80.4	68.5	76.6	73.2	70.2	73.2	75.5	76.8	76.0	70.2	67.3	74.5	87.5	58.5	61.6	72.5	70.0	80.0	71.4	71.4	73.1	66.7	66.1	62.1	79.2
Index of arm	43.1	42.5	43.2	47.9	42.8	45.4	44.1	41.8	42.3	45.9	44.7	42.8	42.4	41.9	43.4	44.5	42.3	42.1	44.9	[illegible]	41.9	46.4	[illegible]	46.3	45.7
Index of finger reach	102.4	101.3	105.0	110.1	104.3	104.4	109.6	106.2	101.9	108.6	105.0	101.2	103.1	101.2	101.2	107.4	103.9	103.3	104.0	98.3	105.8	106.6	104.2	107.3	107.4
Index of height sitting	54.3	55.0	56.0	51.0	55.5	54.2	52.3	56.4	53.8	52.8	54.9	54.5	55.8	55.6	51.1	55.5	56.6	52.2	53.7	54.8	52.5	53.7	56.0	52.4	48.3
Index of width of shoulders	21.4	20.8	23.3	24.4	23.3	23.7	25.1	23.9	22.3	20.9	20.8	21.2	23.0	22.7	20.8	23.1	24.0	23.6	20.7	23.6	22.3	23.3	24.0	23.5	23.4

[1] Slightly deformed. [2] Deformed. [3] Strongly deformed. [4] Head somewhat asymmetrical. Index c.? [5] Father of No. 11. [6] Daughter of Nos. 6, 17. [7] Head flattened behind.
[8] Mother of No. 11. [9] Brother of No. 2. [10] Brother of No. 1.

Papers based largely on Investigations carried on for the Committee on the North-Western Tribes of Canada.

1.—Reports I.–XII. of the Committee on the North-Western Tribes of Canada.

2.—Alex. F. Chamberlain. Der Wettlauf. Eine Sage de Kitonaqa. *Am Ur-Quell,* Bd. III. (1892), S. 212–214.

3.—Einige Wurzeln aus der Sprache der Kitonaqa-Indianer von Britisch-Columbien. *Verh. d. Berl. Anthrop. Ges.* (1893), S. 419–425.

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5.—Notes on the Kootenay Indians, their History, &c. Bd. II. Linguistic Data. *Ibid.*, vol. xvi. (1894), pp. 271–274.

6.—Notes on the Kootenay Indians. Bd. III. Mythology and Folk-lore. *Ibid.*, vol. xvii. (1895), pp. 68–72.

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8.—The Coyote and the Owl (Tales of the Kootenay Indians). *Memoirs of Intern. Congr. of Anthrop.* (1893), Chicago, 1894, pp. 282–284.

9.—A Kootenay Legend: The Coyote and the Mountain-Spirit. *Journ. Amer. Folk-lore,* vol. vii. (1894), pp. 195, 196.

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16.—Kootenay Indian Personal Names. *Ibid.*, pp. 260, 261.

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21.—Vocabulary of the Kwakiutl Language. *Proc. Amer. Phil. Soc.* (1892), pp. 34–82.

22.—Classification of Languages of the North Pacific Coast. *Memoirs of the International Congress of Anthropology.* Chicago, pp. 339–346.

23.—Bella Coola Texts. *Proc. Amer. Phil. Soc.* (1895), pp. 31–48.

24.—Indianische Sagen von der nord-pacifischen Küste Amerikas (Berlin, Asher & Co., 1895), S. vi + 363. Map.

25.—The Social Organization and Religious Ceremonials of the Kwakiutl Indians. *Rep. U.S. Nat. Mus.* (1895), pp. 311–736.

26.—Sprachen-Karte von Britisch-Columbien. *Petermann's Mittheilungen* (1896), No. 1. Map.

27.—The Decorative Art of the Indians of the North Pacific Coast. *Bulletin American Museum of Natural History* (New York, 1896), pp. 123–176.

28.—Franz Boas. Die Entwicklung der Geheim-Bünde der Kwakiutl Indianer. Bastian-Festschrift (1896), S. 435–444.

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30.—Traditions of the Ts'etsā'ut. *Journ. Amer. Folk-lore* (1896), pp. 257–268; and 1897.

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iv.	1–23	1888	233–255
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ix.	1–11	1894	453–463
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xi.	1–23	1896	569–591
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Torres Straits Anthropological Expedition.—Interim Report of the Committee, consisting of Sir W. TURNER (*Chairman*), Professor A. C. HADDON (*Secretary*), Professor M. FOSTER, Dr. J. SCOTT-KELTIE, Professor L. C. MIALL *and* Professor MARSHALL WARD, *appointed to investigate the Anthropology and Natural History of Torres Straits.*

THE party, consisting of Drs. Haddon, Rivers, MacDougall, and Myers, and Messrs. Ray and Wilkin, left London in the 'Duke of Westminster' on March 10, and arrived at Thursday Island on April 22, where Dr. Seligmann joined the expedition. Dr. Haddon adds:—After various delays, Murray Island was reached on May 6; here we occupied a disused Mission House. The whole party stayed in Murray Island for a fortnight, and a number of anthropological and psychological observations were made. As the Rev. J. Chalmers sent the 'Olive Branch' to take on those who wished to proceed to Port Moresby, Mr. Ray, Dr. Seligmann, Mr. Wilkin, and myself took this opportunity of crossing to the mainland. Delena was reached on May 27, and Port Moresby on May 31. In the absence of the Governor, Sir William Macgregor, Mr. Musgrave gave us every assistance, and the 'Peuleule,' a small Government schooner, was put at our disposal for a fortnight. Short visits were paid to Kaile, Kappakappa, &c., and a stay of nearly a fortnight was made at Hula. The annual dance at the neighbouring village of Babaka was witnessed and photographed. This is evidently a fertility dance for the gardens, and probably also for the girls. It is similar to the famous annual dance at Kalo, which is about three and a half miles distant. At Kerepunu we saw and photographed canoes being hollowed out with stone adzes. We have photographed several processes, such as tattooing, fire making, pile driving, pottery manufacture, &c. After our return to Port

Moresby we made a short excursion to the Astrolabe Range, and measured a few Taburi natives. Some mountaineers who visited Port Moresby were also measured and had their eyesight tested. Dr. Seligmann paid a visit to the Rigo district, and had not returned at the time this was written; he will remain some time longer in this part of New Guinea. The rest of us left Port Moresby on July 7, and spent a few days in the neighbourhood of Hall Sound and in the Mekeo district. Murray Island was reached on July 20. Drs. Rivers, MacDougall, and Myers have obtained a large number of observations in experimental psychology, which promise to be of great interest. The whole of the party have enjoyed good health so far, no serious case of illness having occurred.

Silchester Excavation.—Report of the Committee, consisting of Mr. A. J. EVANS (*Chairman*), Mr. JOHN L. MYRES (*Secretary*), *and* Mr. E. W. BRABROOK, *appointed to co-operate with the Silchester Excavation Fund Committee in their Explorations.*

THE excavations at Silchester in 1897 were begun on May 3, and continued, with the usual interval during the harvest, until November 4.

The area selected for excavation included two *insulæ* (XVII. and XVIII.), extending from *insula* III. (which was excavated in 1891) to the south gate, and lying on the west side of the main street through the city from north to south (*v.* plan). The area in question contains about five acres.

The northern margin of *insula* XVII. is entirely filled with the foundations of two large houses of the courtyard type, presenting several unusual features. The southern part of the *insula* contained the remains of a house of the corridor type of early date, portions of apparently two other houses of the same type, and two detached structures warmed by hypocausts and furnished with external furnaces, perhaps for boilers, of which no examples have hitherto been met with at Silchester. Near one of these was discovered a well containing at the bottom a wooden tub in an exceptional state of preservation. It will be added to the collection in the Reading Museum.

Insula XVIII., like XVII., has the northern fringe entirely covered with the foundations of buildings. These belonged to one house of unusual size and plan, and perhaps two other houses. The remainder of the *insula* is unusually free from buildings, and even rubbish pits. It contains, however, towards the south gate, foundations of an interesting corridor house with an attached inclosure containing six circular rubble bases. It is possible that these are the supports for stone querns, and that the building was actually a flour mill. In a well near this building were discovered two more tubs, which have been successfully raised and preserved.

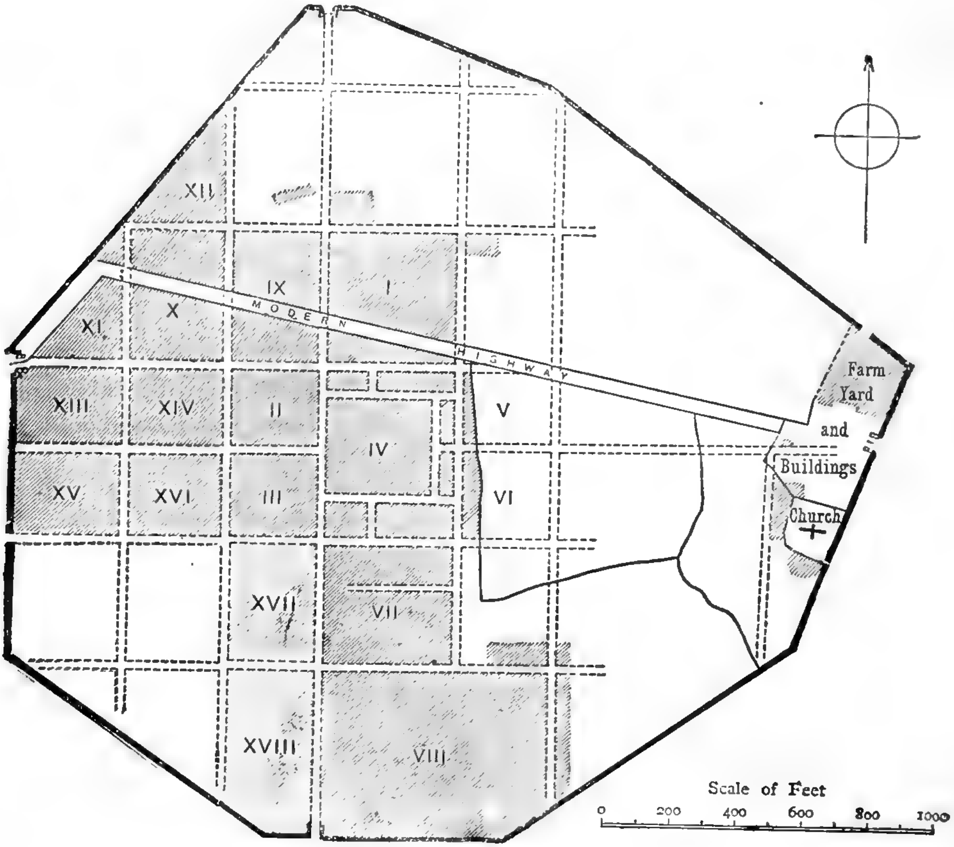
The architectural fragments discovered in 1897 were few in number: among them were a terra-cotta *antefix*, parts of two inscribed tiles and of a marble mortar, a stone slab with moulded edge, apparently portion of a pedestal or some such object, and two fragments of capitals, evidently from the *basilica.*

The finds in bronze, iron, and bone are of the usual character. Among the bronze articles are two good enamelled brooches, several chains, and a curious socketed object surmounted by the head of an eagle—perhaps to fit on a staff. The finds in bone and glass were unimportant.

The pottery includes a number of perfect vessels of different kinds. One of these, a jar of grey ware with painted black bands, is of unusual size, being nearly 2 feet high and 22 inches in diameter.

A detailed account of all the discoveries was laid before the Society of Antiquaries on May 26, 1898, and the objects found were exhibited, as in former years, at Burlington House.

The annexed plan of the Roman town shows the portions excavated down to May, 1898.



It is proposed during the current year to excavate the two *insulæ* south of *insulæ* XV. and XVI. (excavated in 1896). With them must also be included the ground to the south of them, a triangular piece almost as large as a third *insula*. When the examination of this area is completed considerably more than half the city, including the whole of the south-west quarter, will have been systematically excavated and planned. As the *insulæ* and adjoining portions now (1898) under examination cover nearly eight acres, the expenses of the excavations this year will be more than usual.

The Committee therefore ask to be reappointed, with a further grant.

Mental and Physical Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. W. BRABROOK, Dr. J. G. GARSON, *and* Mr. E. WHITE WALLIS. (*Report drawn up by the Secretary.*)

IN presenting our sixth annual report we give a further account of those children whose mental and physical condition renders them unfitted for the public education provided in ordinary elementary day schools. The facts upon which our research is based are the recorded observations of the 1,120 children who appeared to require special care and training, a catalogue of whom was given in our last report (1897)—viz., 597 boys, 523 girls.

Some account of these children is given in the Annual Report (1898) of the Childhood Society, to whom we are indebted for access to the records of those cases.

It is by studying the co-relations of the cases, and the relative frequency with which the main classes of defect are associated in boys and girls, respectively arranged in age-groups, that new information is mostly obtained. This work has proved laborious, and results are given in the table appended. This statement of facts observed may be compared with the results of the examination of 100,000 children seen in ordinary schools.[1]

The facts tabulated show that great difficulties must arise in making any provision for the proper care of these children, who are altogether below the normal or average in bodily and mental power; they show a much greater tendency than average children to become delicate under an adverse environment, especially the girls; this, as might be expected, is most marked in those under seven years of age.

The main classes of defect are indicated in the table by symbols:—A. Defect in development of body; B. Abnormal nerve-signs; C. Low nutrition; D. Mental dulness.

The large proportion of both boys and girls who present 'abnormal nerve-signs' or irregularities in movement, balance, and response in action, shows the importance of trying to remove each such sign of brain-disorderliness in detail by carefully adapted physical training; such abnormal conditions do not appear to pass off naturally in these children, as is shown by the fact that among cases with developmental defect, they are almost as frequent among the older as the younger children.

The remarks made above show that the improvement of the brain con-

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[1] Report on the Scientific Study of the Mental and Physical Conditions of Childhood, with particular reference to children of defective constitution, and with recommendations as to education and training, based on 100,000 children examined. Published at Parkes Museum, Margaret Street, London, W., the office of the Childhood Society.

dition of children below the average in mental and physical development, requires much labour on the part of skilled teachers, combined with good hygienic surroundings, and that such work must necessarily not be estimated by average results.

It appears that research, founded on observation, affords results of scientific and social value, while much remains to be done before any method of mental hygiene can be firmly established.

The Committee desire to be reappointed, to act in conjunction with the Childhood Society, for the scientific study of the mental and physical conditions of children; to assist them in presenting the results of their observations in a duly co-related form they ask a grant of 20*l.* in aid of their work.

TABLE *based on the observation of* 1,120 *children who appeared to require special care and training on physical or mental grounds—Boys* 597, *Girls* 523*—showing the co-relation or the association of the main classes of defects in this Group. The Table is arranged in four columns, giving the percentages for children in the Age-groups and at all ages. The percentages are taken on the number with the main class of defect. Thus: of all cases with developmental defect at all ages* 90 *per cent. of the boys and* 92·3 *per cent. of the girls were mentally dull. Of all the dull children at all ages* 86·3 *per cent. of the boys and* 87·5 *per cent. of the girls also presented abnormal Nerve-signs.*

—	7 years and under		Age 8–10		Age 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
No. of cases—A	*114*	*146*	*151*	*126*	*123*	*80*	*388*	*352*	*All cases with Developmental defect.*
A B	91·2	89·0	92·0	90·5	83·7	85·9	89·2	88·9	Per cent. with Abnormal Nerve-signs.
A C	77·2	83·5	69·5	77·0	48·8	64·1	65·2	76·4	„ „ Low nutrition.
A D	90·3	90·4	91·4	96·0	87·8	92·3	90·0	92·3	„ „ Mental dulness.
A B C	74·5	78·7	68·2	73·0	45·5	57·7	62·8	71·5	„ „ Nerve-signs and Low nutrition.
A B D	85·1	86·3	87·4	88·9	77·2	82·0	83 5	85·8	„ „ Nerve-signs and Dulness.
A C D	73·7	79·5	67·5	76·2	47·1	61·5	72·8	73·8	„ „ Low nutrition and Dulness.
A B C D	72·8	77·4	66·9	73·0	44·6	57·7	61·6	71·0	„ „ Low nutrition and Dulness, and Nerve-signs.
No. of cases—B	*142*	*153*	*186*	*148*	*141*	*115*	*469*	*418*	*All cases with Abnormal Nerve-signs.*
A B	73·2	84·9	74·7	77·0	73·0	58 2	73·7	74·8	Per cent. with Developmental defect.
B C	61·0	76·5	58·6	64·9	41·1	42·6	55·0	62·9	„ „ Low nutrition.
B D	88·7	93·5	86·5	91·8	82·3	85·2	85·9	90·2	„ „ Mental dulness.
A B C	59·8	75·1	55·4	62·1	39·7	39·1	52·0	60·3	„ „ Developmental defect and Low nutrition.
A B D	68·3	82·3	70·9	75·6	67·3	55·3	69·0	72·2	„ „ Developmental defect and Dulness.
B C D	62·7	75·2	57·5	67·8	39·7	40·8	53·7	61·7	„ „ Low nutrition and Dulness.
A B C D	58·5	73·9	54·4	62·1	39·0	39·0	50·9	59·7	„ „ Low nutrition and Dulness, and Developmental defect.
No. of cases—C	*96*	*126*	*115*	*105*	*63*	*57*	*274*	*288*	*All cases with Low nutrition.*
A C	91·6	96·8	91·3	92·4	95·2	87·7	92·3	93·3	Per cent. with Developmental defect.
B C	91·8	92·8	94·7	92·4	92·0	85·9	94·2	91·2	„ „ Abnormal Nerve-signs.
C D	93·7	95·2	93·9	96·2	93·6	89·5	93·8	94·4	„ „ Mental dulness.
A B C	88·5	91·2	89·5	87·6	88·8	79·0	89·1	87·4	„ „ Developmental defect and Nerve-signs.
A C D	87·5	92 0	88·6	91·4	92·0	84 2	89·0	90·2	„ „ Developmental defect and Dulness.
B C D	92·7	91·2	93·0	91·4	88·8	82·5	92·0	89·5	„ „ Nerve-signs and Dulness.
A B C D	86·1	89·6	87·8	87·6	87·2	78·9	87·3	86·7	„ „ Nerve-signs and Dulness, and Developmental defect.

TABLE—*continued.*

—	7 years and under		Age 8–10		Age 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
No. of cases—**D** .	*146*	*157*	*177*	*159*	*144*	*115*	*467*	*431*	*All Dull Children.*
A D . . .	70·5	84·0	77·9	76·1	74·9	62·6	74·7	75·4	Per cent. with Developmental defect.
B D . . .	86·3	91·0	90·0	85·5	80·5	85·2	86·3	87·5	„ „ Abnormal Nerve-signs.
C D . . .	61·6	76·4	61·0	63·5	40·9	44·3	55·0	63·1	„ „ Low nutrition.
A B D . . .	66·4	80·2	74·5	70·4	65·9	55·6	69·4	70·0	„ „ Developmental defect and Nerve-signs.
A C D . . .	57·4	73·9	57·6	60·3	40·3	41·7	52·2	60·3	Per cent. with Developmental defect and Low nutrition.
B C D . . .	60·9	73·2	60·5	60·4	38·8	40·8	53·9	59·8	„ „ Nerve-signs and Low nutrition.
A B C D . .	56·8	71·9	57·0	57·8	38·1	39·0	51·1	58·0	„ „ Nerve-signs and Low nutrition, and Developmental defect.
No. of cases—**A B** .	*104*	*130*	*139*	*114*	*103*	*67*	*346*	*313*	*All children with Developmental defect and Nerve-signs.*
A B C . . .	82·7	88·5	74·1	80·7	54·3	67·1	70·5	80·5	Per cent. with Low nutrition.
A B D . . .	93·2	96·9	95·0	98·2	92·2	95·5	93·6	96·5	„ „ Dulness.
A B C D . .	79·2	86·8	72·6	80·6	53·3	67·1	69·0	79·8	„ „ Dulness and Low nutrition.
No. of cases—**A C** .	*88*	*122*	*105*	*97*	*60*	*50*	*253*	*269*	*All children with Developmental defect and Low nutrition.*
A B C . . .	96·6	94·2	98·0	94·8	93·3	96·6	96·4	93·6	Per cent. with Nerve-signs.
A C D . . .	95·4	95·0	97·1	98·9	96·6	96·0	96·4	96·6	„ „ Dulness.
A B C D . .	94·2	92·5	96·1	94·7	91·6	89·9	94·4	93·0	„ „ Dulness and Nerve-signs.
No. of cases—**A D** .	*103*	*132*	*138*	*121*	*108*	*72*	*349*	*325*	*All children with Developmental defect and Dulness.*
A B D . . .	94·1	95·4	95·6	92·5	88·0	88·8	92·8	92·9	Per cent. with Nerve-signs.
A C D . . .	81·5	87·8	73·9	79·3	53·7	66·6	70·0	80·0	„ „ Low nutrition.
A B C D . .	80·5	85·5	73·1	76·0	50·9	62·5	68·4	77·0	„ „ Low nutrition and Nerve-signs.
No. of cases—**B C** .	*91*	*117*	*109*	*97*	*58*	*49*	*258*	*263*	*All children with Nerve-signs and Low nutrition.*
A B C . . .	93·4	98·3	94·5	94·8	96·5	91·8	94·5	95·8	Per cent. with Developmental defect.
B C D . . .	97·8	98·3	98·1	98·9	96·5	95·9	97·6	98·0	„ „ Dulness.
A B C D . .	91·1	96·5	92·5	94·7	94·7	91·8	92·6	94·9	„ „ Dulness and Developmental defect.
No. of cases—**B D** .	*126*	*143*	*161*	*136*	*116*	*98*	*403*	*377*	*All children with Nerve-signs and Dulness.*
A B D . . .	76·9	88·1	81·9	82·3	81·9	65·3	80·4	80·1	Per cent. with Developmental defect.
B C D . . .	70·6	80·4	66·4	70·5	48·2	49·9	62·5	68·5	„ „ Low nutrition.
A B C D . .	65·8	78·9	62·7	67·5	47·3	45·9	59·3	66·3	„ „ Low nutrition and Developmental defect.
No. of cases—**C D** .	*90*	*120*	*108*	*101*	*59*	*51*	*257*	*272*	*All children with Low nutrition and Dulness.*
A C D . . .	93·3	96·6	94·4	95·0	98·3	94·1	94·9	95·5	Per cent. with Developmental defect.
B C D . . .	98·8	95·8	99·0	95·0	94·9	92·1	98·0	94·8	„ „ Nerve-signs.
A B C D . .	92·2	94·1	93·5	91·0	93·1	88·1	93·0	91·9	„ „ Nerve-signs and Developmental defect.
No. of cases—**A B C**	*85*	*115*	*103*	*92*	*56*	*45*	*244*	*252*	*All children with Developmental defect, Nerve-signs, and Low nutrition.*
A B C D . .	97·6	98·2	99·0	99·9	98·1	99·9	98·0	99·0	Per cent. with Dulness.
No. of cases—**A B D**	*97*	*126*	*132*	*112*	*95*	*64*	*324*	*302*	*All children with Developmental defect, Nerve-signs, and Dulness.*
A B C D . .	85·5	89·5	76·5	82·0	57·8	70·3	73·7	82·7	Per cent. with Low nutrition.
No. of cases—**A C D**	*244*	*260*	*102*	*96*	*58*	*48*	*244*	*260*	*All children with Developmental defect, Low nutrition, and Dulness.*
A B C D . .	98·7	97·3	98·9	95·7	94·7	93·7	97·9	96·0	Per cent. with Nerve-signs.
No. of cases—**B C D**	*252*	*258*	*107*	*96*	*56*	*47*	*252*	*258*	*All children with Nerve-signs Low nutrition, and Dulness.*
A B C D . .	93·2	98·0	93·4	95·7	98·1	95·5	94·7	96·8	Per cent. with Developmental defect.

The Lake Village at Glastonbury.—Third Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor W. BOYD DAWKINS, Sir JOHN EVANS, General PITT-RIVERS, Mr. A. J. EVANS, *and* Mr. A. BULLEID (*Secretary*). (*Drawn up by the Secretary.*)

SINCE presenting the last Report much progress has been made with the exploration of the Lake or Marsh Village near Glastonbury. Twelve more dwelling mounds have been examined, as well as the ground between and around them. The southern end of the settlement has been completely explored, and the investigations have yielded much of importance. The timber substructure in this locality was in a better state of preservation and more massively made than in any part of the village hitherto examined, the arrangement of the logs being exceptionally clear. Some of the dwelling mounds were of more than ordinary interest in their construction, and from the various objects found on and around the floors, and the following observations in connection with them may be specially noticed. Mounds A, B, C, and D formed an interesting group, showing the gradual growth of the village and the construction of dwellings from time to time as they were required; this was easily recognised in these mounds by the floor of one mound overlapping the floor of the mound immediately contiguous to it. The clay of mound A overlapped that of C, B and C that of D. Mound A was the latest construction, D the earliest, B and C were of intermediate date, and the dwellings may have been of contemporary erection. Mounds A, B, and C were of medium size; the foundation of wood was strong and well arranged, especially under mound C. Mound D was remarkable for its series of baked clay hearths, and for a circular basin-shaped depression in the floor of the dwelling within a foot or two of one of the uppermost hearths. The sides and base were hard-baked, and it appeared to have had a semicircular moulded rim raised two or three inches above the level of the floor; it measured two feet across the rim, was nine inches deep, and the sides were nearly straight, sloping downwards and inwards towards the base, which was about twenty-one inches in diameter. It contained fragments of the fallen sides and a little fire ash and charcoal. A somewhat similar depression was discovered in mound J and was described in the last Report. Dwelling mound D was also noteworthy for the number of bone needles, broken and complete, found with numerous splinters and sharp fragments of bone near them. Mound E was of large size, oval in shape, and composed of five layers of clay; it contained two hearths of stone and several of baked clay. In this dwelling mound there were found the remains of what may have formed a small furnace of baked clay, fragments of several three-cornered crucibles, and some small pieces of bronze. Mound F was small and had not the appearance of a dwelling mound. It contained three remarkable groups of clay hearths, each group consisting of three superimposed hearths. Associated with this mound were quantities of pottery and fire ash.

Mound A A: the chief feature in this dwelling mound was the thickness of its clay floor, the vertical measurement of its thickest part being 10 feet; the mound was fairly symmetrical in outline and was about 30 feet in diameter. Beneath the lowest part of the clay, and lying in a layer of brushwood and rushes, part of the framework ostensibly of a loom was discovered; judging from its position, and from the worm-eaten condition of the wood, it had evidently been discarded and thrown away before the first dwelling belonging to this mound was erected. Amongst the timber used in the foundation of the mound were many piles and pieces of wood quite disconnected from the purposes originally intended, and evidently belonging to a previous arrangement at another part of the village.

With reference to the smaller objects, these compare favourably in number with former seasons, especially with regard to pottery, bronze, iron, horn, and glass. Among the finds are the following :—

Stone.—One small celt, fifteen quern stones of various sizes, shapes, and completeness.

Bronze.—Thirty ; including spiral rings, fibulæ and penannular brooches, pieces of tub bands, fragments of bordering, rivet-heads and studs.

Iron.—Fifteen ; three more or less complete adzes, two billhooks, part of a reaping-hook, one file, and several rings.

Lead.—Two spindle whorls.

Glass.—Several blue beads.

Worked Bone.—Fifty-five pieces ; including gouges, needles of various sizes, polishing bones, and other implements.

Horn.—Fifty ; amongst which are several hammer heads, combs, cheek pieces, a knife handle, and a die.

Whorls, loomweights, sling-stones, and pottery were dug up as formerly in quantities.

The following is a summary of the more important finds during the past seven years :—

Stone.—One complete celt, and the half of a second.

One flint saw.

One flint arrow-head.

Thirty quern stones more or less complete.

One hundred and fifty whetstones and hammerstones.

Bronze.—One hundred and sixty-five pieces.

Iron.—Eighty.

Lead.—Thirty.

Amber.—Two complete beads.

Jet.—One ring.

Glass.—Eighteen rings, beads, and pieces.

Crucibles.—Fragments of about twenty.

Worked Bone.—Three hundred and twenty, besides numerous pieces showing knife marks.

Horn.—Two hundred and fifty-five.

Kimmeridge Shale.—Eighteen, including rings and portions of armlets.

Baked Clay other than Pottery.—Many triangular perforated blocks and weights of other shapes, wattle, timber, and finger-marked clay.

Sling pellets of baked and unbaked clay, several thousand.

Spindle whorls, one hundred and thirty-five.

Perforated tusks and teeth, seven.

Human Bones.—Portions of about twenty-five bodies, including four complete skulls.

Pottery and bones of animals, several cart-loads.

Worked Wood.—Portions of tubs, cups, and ladles ; handles, wheel spokes, parts of the framework of one or more looms, and a complete ladder seven feet high.

An Ethnological Survey of Canada.—Second Report of the Committee, consisting of Dr. G. M. DAWSON (*Chairman and Secretary*), Professor D. P. PENHALLOW (*Vice-Chairman*), Mr. E. W. BRABROOK, Professor A. C. HADDON, Mr. E. S. HARTLAND, Sir JOHN G. BOURINOT, Abbé CUOQ, Mr. B. SULTE, Abbé TANGUAY, Mr. C. HILL-TOUT, Mr. DAVID BOYLE, Rev. Dr. SCADDING, Rev. Dr. J. MACLEAN, Dr. MERÉE BEAUCHEMIN, Rev. Dr. G. PATTERSON, Mr. C. N. BELL, Hon. G. W. ROSS, Professor J. MAVOR, *and* Mr. A. F. HUNTER.

AT a meeting of the Committee held on August 20 last in Toronto the resignation of the Chairman from that office was accepted, and Professor Penhallow was nominated as Chairman; but through a misunderstanding this proposal was not brought before the General Committee. Professor Penhallow has since consented to act as Vice-Chairman.

Since the presentation of the first report of this Committee at the Toronto meeting some progress has been made in the further organisation of the work, and some results of interest have been obtained; but the field of work in Canada is so vast and so varied that it has thus far been found possible only to attack limited problems where special opportunities have occurred of enlisting competent observers. As pointed out in connection with the first report, the investigation presents two main branches: (1) That dealing with the white races, and (2) that dealing with the aborigines or Indians. These, however, are not entirely distinct, for a particularly interesting line of inquiry is that relating to the Métis or 'half-breeds,' resulting from the intermixture of the whites and Indians. Nothing has yet been accomplished in the last-named field of work, but it is anticipated that some observers may soon be enlisted for it.

The efforts of the Committee were to some extent handicapped in the first year of its existence by the want of any fund to be employed in the furtherance of its work; but with the grant made by the Association at its last meeting the definite organisation of this work became possible. As a preliminary the Committee issued a general circular, together with Schedules relating to physical types.

Copies of these have been distributed to each member of the Committee, while large numbers of Schedule B, with proportionate numbers of Schedule A, have been placed in the hands of those who are undertaking special work. So far the Committee has distributed about 700 copies of these papers. The Schedules are, with slight modifications, the same as those issued by the Committee for Great Britain, and have been adopted tentatively until their actual use should indicate the special directions in which changes are required. It was found almost immediately that several alterations will be required in the future, the number of facial types in particular being quite inadequate to the requirements of such studies on this continent.

Three sets of anthropometric instruments have been purchased. These have been distributed to Mr. Charles Hill-Tout, of Vancouver, who has already accomplished much good work among the coast tribes of Indians, and who proposes to continue his studies during the present summer; to Mr. A. F. Hunter, of Barrie, Ontario, who has associated with him Dr. F. Tracey, of Toronto, and to Dr. A. C. Hebbert, of Montreal, who proposes to make liberal use of the material to be found in the various military organisations of the city, public institutions, and also, probably, the students of the universities.

The Committee has also purchased a camera specially adapted to its work in the field. This has been placed in the hands of Mr. Hill-Tout, who hopes to secure a large number of negatives during the present summer. These negatives remain the property of the Committee.

Communication with the Committee appointed by the American Association for the Advancement of Science for an Ethnographic Survey of the United States has been opened through its chairman, Dr. Franz Boas, and it is hoped that such co-operation may be secured as will lead to results of mutual advantage.

In pursuance of a resolution of the Committee at the meeting of August 20 in Toronto, communications were opened with the several provincial governments of Canada for the purpose of obtaining, if possible, grants in aid of photographic and other registration involved in the work of the Committee. Nothing has, however, so far resulted from the communications referred to in the way of material aid, although some of the replies received indicate the possibility that such aid may be forthcoming in the future.

Mr. David Boyle, having been commissioned by the Government of Ontario to obtain photographs of some of the Indians of the province in connection with his investigations of Iroquois religious rites, has, however expressed his intention of conducting this work as far as possible in conformity with the requirements of the Committee's schedule.

At the meeting above referred to a resolution was also passed concerning the desirability of taking steps for the preservation of the Serpent Mound in Otonabee township, Ontario; and in October last letters were addressed on the subject to the clerk of the township and to the clerk of Peterborough County Council. At a later date the former replied that his Council considered the work of preserving the mound a provincial one, while the latter stated that the County Council had sent a memorial to the Ontario Government on the subject. Further representations have since been made to the Government, and it is probable that the mound may be acquired next year.

Proceeding upon the lines of investigation adopted by Mr. B. Sulte in regard to the province of Quebec, a preliminary account of which was appended to the last report, a similar inquiry has been undertaken by Mr. A. F. Hunter in regard to the composition of the population of the several counties of the province of Ontario. This is not as yet sufficiently complete for publication, but some idea of its character, and the great interest likely to attach to such a record of the foundation of the people of this province, consisting of the most varied elements, may be gathered from the subjoined preliminary analyses referring to two counties only out of the forty-two for which partial information has already been obtained. These are quoted with Mr. Hunter's permission, and with the object, largely, of inducing a similar analysis of the equally interesting elements brought together in the peopling of New Brunswick, Nova Scotia, and Prince Edward Island.

Simcoe Co.

No.	Immigrants	Date	Townships where settled
1	Sutherlandshire Scots	1820	West Gwillimbury.
2	North of England (small) . .	1820	Penetang Road, W. Gwillimbury.
3	French Canadians . . .	1828	Tiny.
4	Negroes (now chiefly gone) . .	1828	Oro (20 families), Sunnidale.
5	Ulster Protestants (extensive) .	1830	Tecumseth, Essa, Innisfil.
6	Irish Catholic (smaller) . .	1830	Adjala, Vespra, Flos, and Medonte
7	Argyleshire Scots	1832	Nottawasaga, Oro.
8	Lanarkshire and Renfrewshire Scots	1832	Innisfil, Essa.
9	Germans (small)	1832	Nottawasaga.
10	Londonderry	1850	Innisfil.
11	Border District Scots (small) .	1850	Innisfil.
12	Indians (Chippewas) (population, 397)	—	Beausoleil and Christian Islands.

York Co.

No.	Immigrants	Date	Townships where settled
1	Germans (Berczy's 60 families) .	1794	Markham.
2	French Royalists (20 families) .	1798	Yonge St. (King and Whitchurch).
3	Davidites (?) (from New York) .	1800	East Gwillimbury.
4	Eskdale (Dumfriesshire Scots) .	1800	Scarboro.
5	Quakers (from Pennsylvania) .	1805	King and Whitchurch.
6	English (West of England) . .	1820	Richmond Hill (Vaughan and Markham).
—	Pennsylvania Dutch	—	York and Vaughan.
—	Mennonists or Tunkers . .	—	Yonge St. (Whitchurch).
—	Highland Scots	—	Vaughan, King.
—	Annandale (Dumfriesshire) Scots	—	Vaughan.
—	Negroes	—	Vaughan and King.
—	Indians (Chippewas) (population, 118)	—	Georgina and Snake Islands.

In British Columbia the immigrant population is so newly established, and has occurred so largely by individual accretions from sources already most heterogeneous in character, that it seems scarcely possible to pursue with profit a similar method of study. The native races, however, there afford, whether from an ethnological or an archæological point of view, a field of inquiry still wide, although daily narrowing and requiring prompt and efficient action if much is to be placed on record for posterity.

Mr. C. Hill-Tout has been able to accomplish some work in this province, in the record of such facts as have come to his notice, and these are presented in Appendix I. of this report. Mr. Hill-Tout writes as follows :—

'I send in some notes on the folklore of this district, which I have sought to record whenever possible on the lines suggested by the English Committee, and trust they will be found useful. I also enclose a set of (3) photographs in duplicate of a rock-painting found on a cliff about twenty miles from Vancouver. The Indians of the neighbourhood know nothing of it or of its meaning. I venture no opinion upon it myself. In my next report I hope to have more to communicate. I have in hand the following :—

'1. Report on the Archæology of Lytton and its neighbourhood.
'2. Folklore stories from same area.
'3. Vocabulary and Grammar notes on the Ntlakapamuq.
'4. Vocabulary and Grammar notes on the Squamish and Matsqui Yale, and other divisions of the Salish.
'5. Ancient tribal divisions and place-names.
'6. An account of a great confederacy of tribes in the Salish region of "Chilliwack."

'I regard the collection of vocabularies and grammar notes from every dialect and sub-dialect as imperatively necessary for linguistic comparison The lack of these has caused me the loss of much valuable time and retarded my own labours in this field. The work on these lines already done, though excellent on the whole as far as it goes, is altogether too limited and inadequate. If we are ever to be in a position to formulate a law of permutation of letters for the languages of this region it is absolutely necessary that specimens of dialectal difference from every division of a stock be collected. It is not a simple undertaking, and will require considerable time to accomplish, but its importance cannot be over-estimated.

'In this connection it gives me pleasure to inform the Committee that several of the leading anthropologists of Australasia have accepted the evidence of Oceanic affinities of the Kwakiutl-Nootka and Salish stocks as set forth by me in a paper presented at the recent meeting of the Royal Society of Canada. Dr. Carroll, the editor of the "Australasian Anthropological Journal," in particular regards the evidence as practically conclusive.

'The photographic and anthropometric work of the Survey I hope to begin next month, the camera and instruments for which have just come to hand.

'In concluding this report I desire to call the attention of the Committee to the fact that much important archæological work is awaiting development here for lack of funds to carry it on; the necessity for energetically prosecuting which, without further delay if it is to be done at all, I cannot impress too strongly upon all who are interested in this work of the Survey. Every month sees valuable records defaced and obliterated, either by relic hunters or by the progress of civilisation, and the day is not far distant when all trace of the past life and conditions of the aborigines such as are contained in the middens and mounds will be entirely swept away.'

Pending a more complete analysis of the early immigrants from France to Quebec, which it is hoped may take eventually a tabular and numerical form, Mr. B. Sulte has extended the inquiry communicated to your Committee last year by following up the indications of the habits and mode of life of the early colonists by means of such contemporary records as still exist. It is not too much to hope that eventually we may possess a very complete picture of this unique occupation of a part of the North American continent from Old France, and of the formative stages of a new French-speaking people, in all its aspects. The paper forms Appendix II. of this report.

In conclusion the Committee has to report that of the grant entrusted to it at the Toronto meeting a balance of 35*l.* 17*s.* remains. The Committee asks to be reappointed and to be permitted to expend the above-mentioned amount; also that a further grant of 50*l.* may be accorded to it in aid of its investigations, which promise to be of increased importance and value during the ensuing year.

APPENDIX I.

Haida Stories and Beliefs. *By* C. HILL-TOUT.

Cosmogonical Myth and Story of the Origin of the Haida People.

In the remote past *Sha-lănă* ruled in his kingdom in the grey clouds that overshadowed the vast deep. All below was a dark and watery waste. At this time *Yetlth*, the Raven, was the chief servant of Sha-lănă. One day Yetlth ventured to interfere with the conduct of affairs in Cloudland, and was cast forth into the outer world. The Raven flew back and fore over the deep until he became weary. He grew angry at finding no place where he could rest, and beat the water with his wings till it flew up into the clouds on either side of him; and when it fell back again it was transformed into rocks, upon which he rested himself. These rocks grew and extended themselves on every side until they reached from North Island to Cape St. James. Later these rocks became changed into sand, upon which a few trees eventually sprang up and grew, and thus were the Queen Charlotte Islands brought into existence. The Raven now desired someone to assist him in his kingdom, so one day he piled up on the beach two large heaps of clam-shells near by the present site of Sisk, and then transformed them into human beings, whom he made his slaves. They were both of the same sex and female. In a short time these two slaves became dissatisfied with their condition, and complained to their creator, the Raven, that he had mismanaged affairs in making them both of the same sex. The Raven listened in anger to their complaints, but finally altered their condition notwithstanding, and changed one of them into a man, by casting limpet-shells at her. Thus were the progenitors of the Haidas created. The Raven, growing weary of his lonely life, took the woman for his wife, but as she bore him no children he wearied of her and sent her and the man to a spot now called Skidegate. Wearying of his loneliness once more, he determined to revisit his former home in Cloudland and secure, if possible, a beautiful wife from among the daughters of the heavenly chiefs. One bright summer morning he started off on his long journey. He soared upward over the lonely sea until the land he had created appeared to him to be a small mosquito. At last he came to the walls of heaven. He concealed himself until the evening, and then, assuming the form of a bear, scratched a hole in the wall, and thus made his entrance into his former home. The place had greatly changed since he had been an inhabitant there, and consequently he took time to consider everything that he saw, so as to form a similar kingdom on his return to earth. There he found that everyone was considered a god or chief, and all were submissive to the Chief of Light, who still held supreme power as of old. He also found that the Great Chief had divided his kingdom into villages and towns, into lands and seas, and had created a moon and stars, and made a great luminary to rule over all, which was called Jine the Sun. At last he was caught by the hunters of the King and brought into his presence. As the Raven appeared to be a beautiful and tame bear, he was kept as a playmate for the King's youngest son. He now spent three years in intimate relationship with the royal family, and had sufficient time to make careful and necessary observation prior to his descent to the lower world. It was customary for the children in the Land of Light to disguise and transform themselves into bears, seals, and birds. Now it so happened that the Raven, under his disguise of bear, was strolling on the beach one evening, looking for his supper of clams, when he espied three other bears approaching him. He knew at once they were children of a great chief, and, instantly transforming himself into a large eagle, stole the sun, which happened to be setting at the time, also the fire-stick that was used to kindle the fires, and flew over the walls of heaven with one under each wing, together with one of the three children. When the people found that the sun had been stolen, they reported the matter at once to the King. He then ordered his land to be searched, and if they found the thief to throw him down to *Het-gwau-lana*, the chief or ruler of the lower regions. But a messenger arriving, who stated that he had seen a large bird flying over the walls of their city with the sun under his wing, at once all gave chase, and the Raven was followed. In his flight from his pursuers he dropped the child, who fell down through the clouds into the sea close to the Raven's kingdom. The Raven also descended, bearing with him the sun and the fire-stick in safety to the earth. When the child fell into the sea he cried aloud for assistance, and immediately the little fishes came in a great shoal to his aid and carried him on their backs safely to the shore. These fish are very numerous around Rose-spit at the present day, and their forms, say the Haida, have remained dinted in the blue clay of that district from the day when they bore the heaven-born child ashore until now. The great chief was a lover of peace, and consequently did not allow his followers to pursue the Raven down to the earth, as Chief Het-gwau-lana might then be tempted to enter heaven and give them perpetual trouble. So the Raven was unmolested, and another sun was created in heaven by the Great Ruler, who loved light and hated darkness.

Now the Raven thought that he had secured a chief's daughter, but the child turned out to be a chief's son. The Raven loved him exceedingly, and built a house at Rose-spit especially for the accommodation of the child and the sun. The child grew to be very powerful, and had command over all animals, fish, and birds. Whenever he called to the fish they would at once appear and bear him out to sea. Whenever he wished to fly through the air he would call to the birds. They would at once come to bear him wherever he wished to go on their wings. The bears and other animals attended to his daily wants, and supplied him with salmon and berries. The animals, birds, and fish were created by the Raven for the sole benefit of this heaven-born child. The Raven also kept the sun and fire-stick in a very strong and secure room, as he was afraid that his two former slaves would return and steal them. Presently the slave-wife of the Raven returned, and begged to be re-admitted into the Raven's society. The request was granted, and she became once more the mistress of the Raven's household. She took a great interest in the child, and attended to his every wish. In course of time the child grew to be a handsome young man, and began to love the woman. She returned his love, and at last resolved to become his wife. The Raven soon found that they were living as man and wife, and he became very angry, and threatened to kill the woman. This treatment caused the pair to escape from the house and hide themselves in the bush. When they fled from the Raven's house they carried with them a large cedar box, in which the sun and the fire-stick were placed. Day after day, and month after month, they wandered southward without proper nourishment, and in great fear of the Raven. They also carried with them the box containing the sun and the fire-stick. One evening, faint and weary, they sat down near a little creek, and the woman, being very hungry, wept bitterly. Her husband walked a little distance up the stream, and at last found a dead land otter, but they could not eat it, as they had no fire with which to cook it. On the following morning they remembered that they had the fire-stick in the box they were carrying. They at once determined to see if they could produce a fire with it. They were successful, and soon had a good fire, with which they cooked the otter. Having made a hearty meal, they proceeded on their way. When they reached Cape Ball they were hungry again, whereupon the youth began to sing one of the songs taught him in heaven, and the sea receded four miles from the shore, leaving a great whale stranded on the beach. The youth surrounded the whale with a circle of stones and rocks so that it should not escape. This circle of boulders is said to exist to-day. The runaway couple lived on whale flesh until they reached the channel which divides Graham and Moresby Islands, where they settled and built a house. On this spot the village of Skidegate afterwards sprang up. Here they lived for several years in peace and prosperity, and a daughter was born to them, which caused them great joy. In course of time the daughter grew to womanhood, and was an exceedingly beautiful woman, and they would have all been perfectly happy but that there was no prospect of a husband for the maiden.

Year after year passed by, and they had given up all hopes of a husband for their daughter, when one day there came from the North Island, around the west coast, the Raven's male-slave, whom he had made on the beach at Sisk. This forlorn creature now desired the parents to give him their daughter to wife. The father indignantly refused his request, and became very angry at what he considered a great piece of impudence on the part of a clam-shell-made man. How could such a being as he look to wed with the daughter of a heaven-born chief! But the slave was not to be so easily repulsed. He betook himself to the woods surrounding the house, and whenever the father was away would go and talk with the mother. She regarded him as her brother, seeing that they had been created together, and told him all her secrets, and even went so far as to tell him where her husband kept the chest containing the sun which he had stolen from the Raven's house at Rose-spit.

This treasure was stored away in a strongly built house in the woods, where the heaven-born man would frequently go to pray to the gods in the Kingdom of Light. The woman was not wise in thus divulging the whereabouts of her husband's precious treasure; for the slave, on asking a second time for the maiden, and receiving a good kicking from her father,[1] went away in great wrath, vowing that he would be revenged. As soon as night fell, having watched the chief retire to rest, he betook

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[1] It is interesting to note in this connection that the heaven-born man thought nothing of taking the slave for his wife, but was much incensed at the idea of his daughter becoming the wife of a slave. We see that the same notions prevailed among the Haidas generally, for although a chief could marry any of his female slaves, no slave could marry a free-born woman under pain of death.

himself to the treasure-house, and easily entered it through the smoke-hole. He then seized a club that he found on the floor, and smashed the box to pieces, taking care not to injure the sun. When he had wrought this havoc he began to ponder upon his miserable lot in life, and presently, becoming enraged at his ill-fortune, threw down the sun and kicked it to pieces. But the broken parts, instead of falling to the ground, leaped up into the sky, the largest piece becoming a sun, the next biggest a moon, and the other pieces stars. Thus were created the Haida sun and moon and stars, according to the traditions of the ancients.

When the wretched slave became calm once more he speedily realised the danger he now stood in at the hands of the heaven-born man. So before dawn of the following morning he was well on his way to his former abode at North Island. He travelled only by night, hiding himself in the forest during the day, thus avoiding the keen eyes of the Raven and a meeting with his sister's husband. At last he reached home, and for days he sat brooding over his cruel lot until the happy thought struck him that he should do as the Raven had done and go and seek a wife for himself from among the daughters of heaven. But the difficulty was how to get there. This he overcame in the following manner. Taking his bow and arrows in his hand one moonlight night he shot an arrow at the moon, which embedded itself in that luminary's face ; he then shot another into the notch of the first and another into the notch of this again, and so on until he had a line of arrows reaching from the moon to the earth. But all this was not accomplished in one night. According to one tradition he took 364 nights over his task, which later were lengthened into 364 days and nights, which number just makes up the Haida year of 13 months of 28 days each. They account for the discrepancy between their year of 364 days and ours of 365 by saying that the slave occupied one day in climbing the arrow ladder, which has been left out of their reckoning. When the slave had completed the ladder he lost no time in climbing up it into heaven. He arrived there early in the morning, and the first thing that he saw was a beautiful woman swimming in a lake of crystal. He stealthily approached the side where she seemed likely to step ashore after her swim to await her. She presently swam in his direction, and no sooner had she put her foot upon the beach than he seized and dropped with her through the clouds into the sea close by the shore of North Island. As they descended the Raven happened to be flying near the spot, and perceiving something unusual in the air above him watched to see what it was. At first he thought it to be a pair of large eagles, but presently discovered it to be his slave and a beautiful heaven-born woman. No sooner had the slave led his prize into the house than the Raven appeared and demanded that the woman should be given over to him. The slave declining to comply with the request, the Raven became angry, seized the woman, and transformed the man into an invisible spirit and drove him away from his presence for ever. Furthermore, he cursed him and bade him wander over the land and take upon himself the task of caring for the growth and development of every living thing the Raven had created.

Thus the Wanderer, as the slave is now termed by the Haidas, is always busily engaged causing the berries and roots to grow for the support of the people. Every plant, flower, and tree is under his control, and thus it is that Haida-land produces the finest trees for canoes throughout the whole northern region. At the present time the Haidas believe that he is fulfilling his destiny, and they think of him with gratitude and offer him sacrifices of berries, roots, salmon, and bear-grease. These they place in hollow trees that he may eat when he feels hungry. They believe that he wanders upon the earth night and day, and will continue to do so until the end of time, when the Raven will recall him. But woe to the Haidas when this takes place; for the trees and plants, the fish and animals, the fowls of the air, and even the very land itself will pass away and cease to be, and then will their own end come.

Haida Moon Stories.

In early times the Haida moon met with several misadventures, but as every tribe had a tribal moon of its own the consequences were not so serious as they would otherwise have been. When the Raven was in the 'Land of Light' he saw that each tribe there had a separate moon, and he adopted the same plan for the Haidas. The principal moon of the race is that derived from the large splinter kicked off the sun by the 'clam-shell' man in his anger at being refused the hand of the heaven-born man's daughter for wife, as related in the cosmogonical lore of the Haidas. The beaver once ate up the moon of the Masset tribe, and the Raven had to supply another. The sun once chased the moon up the Naas River into the interior of the mainland, where she could find no food. About spring-time, being desperately hungry, she demanded food from her worshippers, who produced the 'candle-fish,' or *ulakan*, which were made to run up the river in great numbers for the purpose. To offset this the sun's worshippers produced the salmon to eat up the ulakans, and it was only at the intervention of the 'Wanderer,' who fought the salmon, that the little fish were rescued.

The moon is not to be insulted with impunity. Once a naughty boy was sent to gather sticks for the fire, but did not want to go, urging that it was dark. His father made him go, telling him that the moon would presently rise and there would be plenty of light. The lad went and stood on the seashore to wait for the moon to rise. As it appeared above the horizon he mocked it by putting his fingers to his nose. Presently a giant came down from the moon and snatched up the boy, and he may now be seen on clear nights in the moon with a bundle of sticks over his shoulder.

Ntlakapamuq Moon Story.—With the above may be compared the belief of the Thompson Indians.

Once there was an old woman who was very meddlesome and interfering. She was perpetually making mischief in the village. The people endured her as long as they could, but at last determined they could stand her no longer. They agreed to seek a new settlement and leave her behind. So each family got out their canoes, and loaded them with all their belongings and paddled away. As each left, the old woman begged to be taken on board, but was told that the canoe was too full already, that the next boat would be best for her. They all made the same excuse, and presently the last canoe passed her and she was left behind. As she sat bewailing her lot the moon rose, and she called to it to have compassion on her. The moon came down almost to the ground to see what the old woman was wailing about, and she, seizing the opportunity, leaped up into it and was carried up into the sky. In her hand as she leaped she held a little birch-bark bucket, and on clear nights she can still be seen in the moon with her little bucket in her hand.

Haida Beliefs, &c.

Frog.—Among the Haidas the frog is regarded as the embodiment of wisdom, whence the medicine-man obtains gifts from his favourite spirits.

Marriage Customs.—When a man fancied a girl for his wife he went to her uncle, the brother of her mother (who alone has any voice in the matter), and make overtures to him by means of presents. The uncle being willing, the man then makes known his wishes to the young woman. She thereupon procures the assistance of her companions and prepares for the ceremony. When she is ready the man goes to her dwelling, a great feast is then made to which friends of both parties are invited, and during the course of the feast he rises and claims her as his wife in the presence of all assembled. On the following day she and her friends go to his house, when a second feast is made, after which they are regarded as man and wife.

Weasel Belief.

The weasel causes great alarm and fear among the Haidas. He is the heart-eater and man-slayer. He is supposed to enter the dwellings stealthily at night and pass into the man's interior through the fundament. The weasel then feeds upon the man's heart and he shortly dies. This happens to those who do not honour the Raven by doffing their caps when a bird of this species flies over heads.

The Myth of Tou; or, the Little Mountain and the Spider.

On the shores of Masset Inlet a long time ago lived two little mountains. One was a good mountain and the other was not. The good mountain was satisfied with his lot, with his food of hair-seal and halibut, was blessed with a good digestion, and an even temper. The bad brother Tou wanted dog-fish, and grumbled and growled all the time because the chief of the waters would not let him have his sister's rations as well as his own. At last he determined to change his place of abode, and one moonlight night he set out on his journey. He travelled fifty miles, tearing up the ground and making a dreadful noise as he went, and finally pulled up on the Northern Coast near Rose-spit, where the dog-fish abound. Here he stayed, and his walls of black basalt now tower 200 or 300 feet above the shore. He now gets all the dogfish he desires, but still he is not satisfied. A large spider lives in the clouds over his head, which makes itself very disagreeable to him by pulling his hair and screaming and howling in his ears.

This spider caused much disquietude among the Haidas themselves also. No one would venture to go to sleep near its abode. But once a Haida warrior determined to seek out the spider and fight with it. So he took a barbed spear, a wooden drum, and a big whistle and went to seek the enemy. He made such a din with his drum and whistle that the spider came down to see what was the matter. When the spider perceived the man he came at him open-mouthed, screaming and growling the while. The warrior thrust his spear into the terrible creature's jaws, which stopped its noise and prevented it from closing its mouth. To the spear was attached a long cord, with which the man now tethered the spider to a tree so that it could not get away. The spider finding itself fast grew terribly angry, and began to break up the mountain, and hurled large masses of it at the warrior, who had much ado to avoid them. At last the spider succumbed to hunger and died; and its body was then cut into extremely small pieces by the female relatives of the warrior. But though the spider no longer troubles Tou, he has not ceased to grumble yet.

Tidal Wave Myths.

The tidal waves are believed by the Haidas to be caused by three sisters who dwell on the West Coast. When they are annoyed in any way they revenge themselves by raising these great waves and smashing the canoes of the Haidas and drowning their occupants. The devil-doctor is the only intermediary between the sisters and the people, and his services must be well paid for before he acts.

Tschimose Myth.

The Haidas belief in the existence of a fearful man-eating monster, who lives half in and half out of the sea. This dreadful being is seen once in about fifteen years, and his appearance presages a time of famine or pestilence and sickness.

The Killer-whale Myth.

When a Haida is drowned it is believed that his spirit is translated to the body of a Killer-whale. These whales were therefore formerly much honoured, and never killed by the Haidas. The appearance of one of them off the shore in front of an Indian's dwelling is always regarded as a 'call' to some member of the household, who will shortly meet with his death by drowning.

Land-otter Myth.

The Haidas believe that the land-otter has the power to enchant men. He meets hunters and wanderers in the forest in the guise of a beautiful maiden, who says to the victim, 'Come and sit down with me.' The wise man is able to detect the enchantress by the pronunciation of the words she uses, and so escapes her charms. The unwary, yielding to her wiles, become her slaves, or are found wandering in the woods bereft of their senses. She is also supposed sometimes to place certain leaves which have magical qualities in the springs frequented by the people. Hence, before taking a drink the Haida first throws a little water over the right shoulder, saying at the same time, 'Land-otter, land-otter, go from me!'

The Thunder-eagle Myth.

This widespread myth is found also among the Haidas. They regard the thunder-eagle as their deadliest foe. They suppose that he dwells as a lonely god among the most awful recesses of the mountains, and that when he is hungry he robes himself in eagle form and swoops down upon the land, darkening it with the shadow of his widespread wings, whose motions give rise to the thunder. The lightning is supposed to come from the tongue of a fish which the thunder-eagle carries under his pinions.

The Mouse Myth.

This myth of the mouse is one of the most firmly implanted in the minds of the Haidas. It enters very intimately into their lives. The younger members are beginning to laugh at the notions connected with it now, but their elders still firmly believe in them. To them the harmless little rodent is a veritable demon. They believe that its home is the stomach of human beings, and that every person has one or more of them in his stomach. If a person is bad-tempered, immoral, passionate, a liar, thief, &c., they attribute these qualities in him to the mice-demons in his stomach. Again, if a person is taken ill, his father turns all his goods and belongings out of doors; he next proceeds to catch a mouse. Having secured one, he puts it into a small box and gives it plenty of grease to eat. He abstains himself from all food for three days. Each morning he takes the box and mouse down to the sea and drinks about a quart of salt water He then returns and throws himself on his bed, places the box containing the mouse under his pillow, and goes to sleep. He sleeps throughout the day and following night, sentinels being placed about the house to prevent anyone from disturbing him or making a noise. In the morning he rises, goes down to the beach, drinks his quart of salt water, and returns to sleep till the following morning. He keeps this up for three successive days. If during this while he imagines or dreams that a person or spirit from the invisible world has appeared and revealed to him the name of the individual responsible for his son's illness, he straightway rises and goes to this individual and charges him with the act, and demands his reasons for attacking his son in this manner. If, however, no vision or dream comes to him, after the third day has passed he takes the mouse in his hand and goes into every house in the place, and holds the mouse in front of each person until he is satisfied that he has found the individual guilty of the offence. If the mouse nods its head twice before anyone, it is to the Haidas plain proof that the culprit is revealed. In the older days this person would be found dead in the woods a little while after.

If one of these harmless little creatures has scampered over any food the Haidas would never think of eating it. They believe it is then impregnated with poison. It is all thrown into a fire and consumed.

Cloud Myth.

When the clouds hang low the Haidas believe that a soul is being snatched away, and expect to see one of their number shortly die.

Transmigration of Soul.

The Haidas believe in the transmigration of souls in this way: If, when a person dies, the nearest female relative of the deceased is about to be delivered of a child, the soul of the deceased will pass into the body of the new-born infant and live again.

Specimens of Songs of the Haida.

Berry Song.

Whit squate, squate, whit squate squate
  A la whit, a la whit:
Kalunga olthē, kalunga olthē
  Siamzi whē, siamzi whe whit.

The above is an invocation to a bird called the 'whit,' which is supposed to ripen the berries. It is besought to bring many large and nicely coloured ones.

Ridicule Song.

Yelthgowasu kingung
Laou wangung, laou shugung
Laou iching, laou iching
Laou kanga ? laou kanga ?
Yelthgowasu kingun.

Translation.—NOTE.—Yelthgowasu is a man's name.

Yelthgowas sees it,
He does it, he says it,
He it is, he it is ;
Did he see it ? did he see it ?
Yelthgowas saw it.

Devil Doctor's Song to the Spirit of the North Wind.

Ada adda di whi silthliga adi gwudakoustloga
Dikwun kwul dungalthdagang alskid ada hi hi hi e.

Ditto to the East Wind.

Oh, hi a a, oh hi a a ohi a a a a
Kalke kona kish a a a
A skidje a dung a thu kagwalgudied
Kalke kona kish a a a ho.

NOTE.—'Skidje' is the daughter of the mist and east wind, but has now become a diver on account of her poverty. She and her father, the east wind, are invoked to cause fair weather and keep off snow and ice.

Wind Song.

Di whiskada gwe he he
Di whiskada gwe he he
Hangi kwungust, di whiskada agwi.

Translation of above.

The wind is whistling to me,
The wind is whistling to me,
The wind is blowing boisterously in my face.

Specimen of Haida Syntax.

Itil kwogada daha itil Aunguans,
(Us love you our Father great ;)
Altsulth heth il istaiang kit unga,
(Therefore down he sent son his ;)
Jesus Christ nung alth etil kaginsh is,
(Jesus Christ he our Saviour is ;)
Altsulth Jesus itil hagunan kwotalang,
(Therefore Jesus us for died.)

I am indebted to the Rev. Mr. Harrison for information on the Haidas.

APPENDIX II.

Customs and Habits of Earliest Settlers of Canada.

By BENJAMIN SULTE.

It is intended in this paper to explain the mode of living of the explorers, and afterwards of the first settlers on the shores of the St. Lawrence, as well as the modifications they introduced in their customs, habits, &c., in order to conform themselves to the requirements of the new country. There are two phases to be examined in connection with this: from 1535 to 1631, and from 1632 to 1660 or thereabout.

Let us follow, first, the explorers of Eastern Canada, and see who they were, how they acted in regard to climate, dress, and food. The men of Cartier and Roberval (1535–44) were all Bretons and unaccustomed to residence elsewhere than at home in Brittany. The result was that most of them perished by the effect of cold, bad nourishment, disease, and despair, whilst the present French Canadian would not experience any hardship were he to find himself in the same situation.

When Champlain (1604–30) describes the miseries of life in Acadia and the lower St. Lawrence, he merely states for our information that his men and himself had acquired very little knowledge in that sense above that of previous explorers. They still persisted in depending upon the provisions brought from France—salt pork, beans, flour, mostly affected by the influence of weather, time, &c., and not always abundant enough to cover the period at the end of which a fresh supply would be sent. It was considered good fortune when one or two of the men could handle a gun and shoot some game. As for the art of fishing, nobody seems to have known anything of it, and these people starved alongside of a world of plenty, since they had the rivers, and lakes, and the forests lying all around their miserable camps.

The only superiority of the Champlain men over the crew of Cartier consisted in the building of a house or two, but even at this they showed a rather poor conception of comfort. Chauvin, in 1599, went to Tadoussac and left there sixteen of his followers to winter, without the elementary precautions of providing them with eatables and warm quarters. In the spring of 1600 the place was found empty, and none of the men are mentioned afterwards. The Indians had always been friendly to them, but could not take such inexperienced folks to the woods. The same thing happened to De Monts (1604–5) in Acadia, when nearly all his party died of scorbutic disease and want of food during the rough season. Champlain, who knew these facts recorded from the years of Cartier, did not succeed any better in 1608, when he lost twenty men out of twenty-eight. This was repeated yearly afterwards, but in smaller proportions.

Even as late as 1627 the 'winter residents' of Quebec were ignorant of the advantage of cutting trees during the summer in order to prepare dry fuel for the October–April season. It was Pontgravé who advised them to do so, and no doubt they recognised it was a great forethought. They used to pick up whatever the wind would blow down of branches in the forest, and if that material proved insufficient on extremely cold days, then they tried their hands at felling some trees near by and supplying them in blocks to the steward's room. No wonder that the writings of the period in question so often complained of the evil of smoke and the small quantity of heat produced by the burning of such green wood. Stoves being unknown to the *hivernants* in Canada, a caboose supplied the place of that indispensable adjustment, and the men, unoccupied most of the time, slept around it, starved there, got sick and died on the spot, one after the other, as a matter of course. Father Biard, evidently ahead of his generation, once made the remark that an iron box (a stove) such as used in Germany was preferable by far to the poisonous system of caboose. The improvement made by Champlain in his house at Quebec consisted in substituting an ordinary chimney for the open fireplace above alluded to. It is likely that Louis Hebert in 1617, and Guillaume Couillard about 1620, built similar smoke-escapes in their homes; they also had the good sense to fit door and window sashes so as both to close hermetically and open easily when required. These marvels were not to be surpassed for a long while after that.

The equipment provided for the men of Cartier, Roberval, Chauvin, De Monts, and Champlain was not generally suitable in Canada. Slouch felt hats are not equal to fur caps in winter; boots and shoes of European fabrics could not compete with the moccasins; and as for overcoats, it may be said they were not fit for the climate. Gloves, trousers, and underclothes adapted to the exigencies of 30° below zero constituted a puzzle for these people. Snowshoes and mitts were doubtless adopted at an early date from the Indians.

It was well known throughout France that Canada was a purgatory for civilised people, and would never be settled by Christians.

Building houses was not customary in Quebec until 1632, because the men (all without families) were located for the winter in what was called the fort. As it was not intended to increase the colony, no carpenter was needed for other purposes than to keep the ships in repair.

This awkward situation remained the same during twenty-six years. What was the cause of it? Simply this: the men for Canada were recruited from the working classes (if not of the worst), through the suburbs of large cities and towns, the very individuals who were the least fit for the trials to be met in a wild country. For instance, a shoemaker is not called upon to find his daily bread and meat by sowing wheat, planting vegetables, or hunting and fishing. Those men do not know how to manufacture clothing or to dress themselves appropriately; neither can they prepare beaver or other skins to make a soft and warm garment. Their 'coaling' power was also limited, for the wood standing in the forest was for them a foreign product, accustomed as they were to receive their fuel all cut up and dry at the door of their homes. Necessity, it is said, is the mother of invention; but this only applies to people who already live by inventions, such as poor country folks—not the 'citizens' who depend upon the shops in their street. Furthermore, those who came to Canada 'took no stock' in the future of the country, and they returned to France (when not buried here) in haste, without having had time to learn much. The fur companies did not ask them to become Canadians. They had no reason to turn a new leaf and devise a means of life so completely different from their habits and aspirations.

Now we will close this unfortunate period by saying that about twelve or fifteen of the youngest men, still employed in the neighbourhood of Quebec in 1631, were merged into the subsequent immigration and became equally competent with that new formation, *i.e.*, the actual settlers. This little squad, strange to say, was all from Normandy, and every one of them educated far more than ordinary people: this was the only good result of a century of wrong management in the affairs of Canada.

Coming to the second phase, we have to introduce farmers of Perche, Beauce, Normandy, and Picardy, numbering forty-five, from 1632 to 1640, besides twenty-six from Champagne, Lorraine, Brie, Poitou, Maine, during the same nine years. This period gives an average of eight settlers per year only, which may be considered the proportion for twenty years afterwards.

The group of Perche took the lead from 1632 and kept it for ever. They came married, bringing their farm implements, cattle, &c., and in less than two years after their arrival conquered the soil, learned how to face the climate, and made themselves literally at home, where their predecessors had miserably perished by scores during many years.

The typical Percherons knew the way to clear the forest, because their country was covered (especially in those days) with trees. They produced all sorts of grain, poultry, cattle, pigs, &c., and so they did in Canada from the outset. Every woman had a trade of her own—the men also. Take Beauport, near Quebec, as an example: the first ten or twelve agricultural families located there were composed of a stonemason, a carpenter, a tiler, slater or thatcher, a blacksmith (often called armourer), a miller, a shoemaker, a ropemaker, a leather-dresser, and two or three weavers. Before the clothes brought from France were worn out the 'Canadian' manufacture supplied the little colony with fresh woollen stuff of various fabrics from serge and camlet to much thicker cloths, as well as linen made of their culture of flax. It soon became a saying that the 'habitant' (so named by contrast with the roving fur-trader) needs no help from France, except in the line of iron and steel tools and firelocks. From head to feet they could provide for themselves; their table was well supplied, their houses comfortable; in fact they lived in luxury. The culinary art had many adepts amongst them, and this has been transmitted through generations.

The hygienic aspect of the situation must have been well understood by those early settlers, because not even the children were affected by the influence of the new climate and habits of life. Scorbutic diseases disappeared from 1632—that is to say, never prevailed amongst actual settlers or habitants, but continued to follow the men sent to the advanced posts for a winter or two in the pursuit of the fur trade.

Boots and shoes brought from France soon became known as *bottes et souliers françois*, to be used indoors on special occasions only. *Bottes et souliers sauvages* served all other purposes at every season. The long overcoat, or *capot*, made of coarse woollen cloth with a nap on one side (frieze) called *bure* in French, is a remarkable instance of their ingenuity. This coat has a hood attached to the collar and dropping behind: it is buttoned up and down, double-breast, and made tight around the body by a wide and long woollen sash of bright colours, altogether an immense improvement over the 'caban' or dreadnought-coat of the mariners, well known in England and France. Their mode of colonisation also differed from that which could have been expected, considering that in France the country people are centralised in villages somewhat away from the fields they cultivate. The first attempt made in Canada to lay out farms (1632) consisted in having them in a row facing the river and distant from one another about four arpents: each lot of land measured forty arpents deep, making one hundred and sixty square arpents for a farm. This system was adopted by the whole of the colony as it gradually got settled—notwithstanding the authorities who were in favour of the formation of villages in preference to what they styled a 'dispersed order.' The advantage of such an arrangement is to bring the house a few steps from the river; to permit easy access to the public road situate between the house and the river; to keep social intercourse as close as possible by the vicinity of neighbours addicted to the same profession. In a case where twenty habitants so covered eighty to one hundred arpents on a line following the water's edge, they did nothing else but open a street, and so they could visit each other with facility at all times. Four feet deep of snow in the winter was beaten down within two hours by the passage of forty or fifty horses and men. This of course was at first done on snowshoes until horses were introduced (1665), and then this arrangement worked to perfection. That was the time that the French carriole—on wheels—was dismounted, put on runners, and became the comfortable family vehicle so popular in Canada East during the snowy season.

Anyone who will peruse the numerous works containing letters and documents relative to the years 1632–70 in this colony may obtain more information on this subject. In conclusion I may mention inventories (existing in original) of household effects, which afford a fair idea of the contents of the early residences, such as furniture and utensils, from 1640 to 1670. The kitchen has a special fireplace where the cooking was done. Two or three chimneys (brick or stone) heated the main part of the house. Wooden floors everywhere, smooth, clean, covered with rug-carpets. Sleeping rooms upstairs. Double doors and windows for the winter. A large and well-lighted cellar, with a compartment for ice to be used during the summer months. The four walls of the building made of thick lumber placed flat one over the other in a horizontal position. No chairs, but forms for two, four, or six persons. No wine, but cider and beer sometimes, also guildive, a second-class brandy, and rum. Flannel, serge, heavy cloth, linens of various descriptions, all home-made, and of which the farmer's wife felt proud, were stored in cupboards or closets. The population came altogether from that part of France where cider and beer were most in use; they immediately started a brewery and a plantation of apples on arriving in Canada. Guildive and rum came from France.

The evident superiority of the men who came immediately after 1631 over those who had previously tried to reside here is the object I wish to impress upon the mind of the reader. The manner in which they practised agriculture, their habits, customs, dresses, all things belonging to them, were afterwards adopted by all the new comers. Such is the evidence very clearly shown by our archives.

Ethnographical Survey of the United Kingdom.—Sixth Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Dr. FRANCIS GALTON, Dr. J. G. GARSON, Dr. A. C. HADDON, Dr. JOSEPH ANDERSON, Mr. J. ROMILLY ALLEN, Dr. J. BEDDOE, Mr. W. CROOKE, Professor D. J. CUNNINGHAM, Professor W. BOYD DAWKINS, Mr. ARTHUR J. EVANS, Mr. F. G. HILTON PRICE, Sir H. HOWORTH, Professor R. MELDOLA, General PITT-RIVERS, Mr. E. G. RAVENSTEIN, Dr. H. O. FORBES, *and* Mr. E. SIDNEY HARTLAND (*Secretary*). (*Drawn up by the Secretary.*)

1. As in previous years, the Committee has had the advantage of the co-operation of several gentlemen, not members of the Association, but delegates of various learned bodies interested in the Survey.

Mr. George Payne, one of the delegates of the Society of Antiquaries; Mr. E. Clodd, Mr. G. L. Gomme, and Mr. Joseph Jacobs, representing the Folklore Society; Sir C. M. Kennedy, K.C.M.G., representing the Royal Statistical Society; Mr. Edward Laws, the Venerable Archdeacon Thomas, Mr. S. W. Williams, and Professor John Rhys, representing the Cambrian Archæological Association; and Dr. C. R. Browne, a representative of the Royal Irish Academy, have continued their valuable services. Other members of the Committee are delegated by the Anthropological Institute.

2. Having last year, in its Fifth Report, recapitulated the steps taken towards the fulfilment of the duty entrusted to the Committee, it is unnecessary to do more here than make a brief record of its further proceedings.

3. At the time of the last report the Committee had appointed the Rev. H. M. B. Reid to carry on the work in Galloway initiated by the late Rev. Dr. Gregor, and the Rev. Elias Owen, F.S.A., and Dr. H. Colley March as special observers in North Wales and Dorsetshire respectively.

4. No complete report has yet been received from the two former gentlemen; but the Rev. H. M. B. Reid has sent some notes of customs, in anticipation of a fuller report. Dr. Colley March devoted some weeks of the autumn of last year to inquiries and observations in Dorsetshire. His preliminary report on the folklore of the district has been received. In addition to this, he measured and took photographs of a number of typical inhabitants. Dr. March has kindly undertaken to proceed with his inquiries, and it is hoped that, if the Committee be re-appointed, a further and fuller report may be made next year. Meanwhile, the physical measurements and photographs are postponed, to be dealt with when his inquiries in the district are completed. Dr. March has also forwarded a sketch and photographs of the famous Giant of Cerne Abbas.

5. The Committee is indebted to Captain Bryan J. Jones for a report of some interesting traditions and superstitions collected by him at Kilcurry, co. Louth, Ireland, together with a careful sketch-map of the village, showing the spots believed to be haunted and the route traditionally assigned to the 'Dead Coach.'

6. The Committee has also to acknowledge communications from Mr. John Fielder Child, of observations at Farnborough, Hants; Mr. Adam Lander, of observations in Ross-shire, Scotland; and the Right Rev. the Lord Bishop of Barrow-in-Furness of observations at Churt, Surrey.

7. The Committee has received, by the kindness of Mrs. and Miss Gregor, a wooden mould for making horn spoons, obtained by the late Rev. Dr. Gregor in Galloway. This interesting relic of the domestic arrangements of the past has been handed to the Folklore Society, and deposited by them in their case in the Cambridge University Museum.

8. Early in the present year the Committee, by the courtesy of the Anthropological Institute, the Royal Archæological Institute, and the Folklore Society, distributed to the members of those bodies a circular calling attention to the objects and methods of the Committee's inquiries, and asking for assistance. Several replies were received, but, with the exception of Captain Jones's report on the traditions of Kilcurry, the Committee regrets to be unable as yet to record any definite result.

9. In view of this the Committee desires to call attention to paragraphs 18–26 of its last year's Report, and to emphasise the fact that, while the

whole scheme of the Committee's inquiries includes a number of subjects, thus appealing to persons interested and capable of rendering assistance in various ways, it is not considered necessary for each observer to deal with them all. Having regard to the movements of population and the spread of education, some subjects, such as current traditions and beliefs, and dialect, are more immediately pressing than others equally important for the purposes of the Committee.

10. Moreover, it is a question whether the time has not arrived for considering some practicable suggestion for employing a paid and experienced assistant to make observations in parts of the country which may be expected to yield results of special value for the inquiries.

11. The grant appropriated to the Committee at the Toronto meeting has not been drawn, and some balance remains in hand from that appropriated at the Liverpool meeting. The Committee asks to be re-appointed and permitted to use this unexpended balance, and to be provided with a further grant, so as to have at its disposal the total sum of 50*l.* during the coming year.

Functional Activity of Nerve Cells.—Second Report of the Committee, consisting of Dr. W. H. GASKELL (*Chairman*), Professors BURDON SANDERSON, M. FOSTER, E. A. SCHÄFER, J. G. MCKENDRICK, W. D. HALLIBURTON, J. B. HAYCRAFT, F. GOTCH, C. S. SHERRINGTON, *and* A. B. MACALLUM, Dr. J. N. LANGLEY, Dr. G. MANN, *and* Dr. A. WALLER (*Secretary*), *appointed to investigate the changes which are associated with the Functional Activity of Nerve Cells and their Peripheral Extensions.*

THE following investigations have been carried out during the past year :—

Dr. G. Mann : Histological changes in nerve cells.

Professor Boyce and Dr. Warrington : Changes in nerve cells after section of nerve fibres.

Dr. J. L. Bunch : Position of cell stations on the course of sympathetic nerves.

Professor Sherrington : Activity of nerve centres correlating antagonistic muscles.

Professor Gotch : Electrical changes in nerve fibres during activity.

Professor Halliburton and Dr. Mott : Effects of neurine and choline upon the vascular nervous system.

Professor Waymouth Reid and Dr. Macdonald : Electro-motive changes in the phrenic nerve.

Dr. Anderson : On the myelination of nerve fibres.

The results of several of these investigations have been already in part published in the 'Journal of Physiology,' and in [the 'Proceedings of the Royal Society,' 1897 and 1898. In addition the following reports have been received.

APPENDICES.

I. *On Structural Alterations observed in Nerve Cells.*

By W. B. Warrington, *M.D.*

A paper was published in the 'Journal of Physiology,' vol. xxiii., on the structural alterations observed in nerve cells :—

(1) Of the anterior horns of the spinal cord after section of the posterior roots.

(2) After division of the axons belonging to them.

Summary of Part I.

Records of observations made on eight cats and one monkey are given.

These observations show that after sections of several posterior roots, from the fifth to the ninth post-thoracic inclusive, a considerable percentage of obviously altered cells are found : their distribution in the case of the cat is practically limited to the seventh and eighth segments, and especially to the postero-lateral group of cells in those segments.

In the monkey the upper part of the seventh segment is picked out.

The effect is to a very slight extent a crossed one, and presents the remarkable feature that more affected cells were found in the sixth segment of the crossed side than on the side of the lesion.

In the cervical region, in one case, similar but slight changes were found limited to the seventh segment; in the other the spinal cord was practically normal.

The significance of these results and of their limitation to certain cell groups is discussed, and the view adopted that the structural changes correspond to the altered functional state of motor cells deprived of the afferent impulses which impinge upon them.

Summary of Part II.

Observations were made on eight cats, one monkey, and on material supplied from the autopsy room (I am indebted for the material in the case of the monkey and one cat to Professor Sherrington).

The observations show that—

1. Distinct and easily recognisable changes in nearly all the cells of a segment of the spinal cord are found on the side of the lesion after section of an anterior root.

2. Similar but less marked changes follow division of the facial nerve, and still less distinct alteration after division of the oculomotorius nerve.

3. The fate of such altered cells and the ultimate condition of the nucleus of origin are not yet definitely ascertained.

4. The age and nature of the animal experimented on is a factor in

determining the rapidity and degree of alteration met with in the nerve cells.

A paper on the Morbid Anatomy of a case of lead-poisoning will appear in the spring number of 'Brain,' by Dr. Laslett and myself.

An examination of the various segments of the spinal cord and the corresponding nerves was made, and it was found that certain cells in the anterior horns showed changes comparable with those described after division of an anterior root, and that these altered cells were limited to these segments from which the most degenerated peripheral nerves and anterior roots were derived, the posterior roots being in all cases normal.

II. *On Excitatory Electrical Changes in Nerve.*

By FRANCIS GOTCH, *F.R.S., and* G. J. BURCH, *M.A.*

The authors have employed the apparatus described in their previous report, and have succeeded in obtaining photographic records of the movement of the mercurial meniscus of the capillary electrometer due to the electromotive changes produced in nerve in response to a single excitation. The results have been briefly set forth in communications both to the Physiological Society[1] and the Royal Society.[2] In these communications it will be seen that the authors have studied the influence of varying conditions of the nerve upon the character of the electrical response as indicated by that of the photographic record.

The records themselves are sufficiently large to permit the determination of the time relations of the electromotive changes, and thus afford data for the more precise estimation of the characters of the propagated excitatory state constituting the so-called 'nervous impulse.'

From an analysis of the records it is thus possible to obtain a history of the amount and extent of the change in any one portion of the nerve when the state of excitation reaches this portion, this state having been started in the nerve trunk by a single stimulus. When two contacts on the uninjured nerve are arranged in connection with the instrument, a change of the above character occurs, first under the proximal contact (*i.e.* that nearest the seat of excitation), and later under the distal one; the algebraic sum of the two effects is a rapid biphasic change indicated in the photographic record by a spike. Each complete change under one contact only is indicated in the record by a sudden rise, followed by a prolonged tail or after effect; the E.M.F. of the former attaining a maximum of ·03 volt with great rapidity, that of the latter a maximum of ·003 volt $\frac{1}{100}$ second later.

Starting with these fundamental characteristics, the authors have examined the influence of the following changes of condition: (1) electrolytic changes produced by polarising currents; (2) persistent electromotive changes produced by localised injury; (3) local alterations in temperature; (4) variations in the intensity of the stimulus; (5) the frequent repetition of the stimulus; (6) CO_2 gas, &c. The research is now being extended to comprise the electromotive effects produced in mammalian nerves, both peripheral nerve trunks and nerve roots, as also those known to exist in the spinal cord.

Endeavours are also being made to obtain records of the changes in mixed nerves, roots and cord, evoked by reflex discharge of the central

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[1] *Journal of Physiology*, vol. xxii. (xxxii.).

[2] *Proc. Roy. Soc.*, vol. lxiii. 1898, p. 300.

nervous system, in the hope that the character of the discharge from the efferent nerve cells may be thus elucidated.

The research has, so far, amply fulfilled the expectations of the authors, and it is particularly gratifying to them to feel that the results are not dependent upon the possession of a particular capillary electrometer. This is shown by the circumstance that when, owing to an unfortunate accident, the instrument was broken, a second one, made for the purpose, has given, if anything, better results than that originally employed. It appears, therefore, that any electrometer of adequate sensitiveness and sufficient rapidity will furnish records of the change, if appropriately used. Since every delicate capillary electrometer is, from the nature of things, a perishable instrument, this fact is one of great importance for the prosecution of the present research.

III. *The Effects upon Blood-pressure produced by the Intra-venous Injection of Fluids containing Choline, Neurine, and Allied Substances. By* F. W. Mott, *M.D., F.R.S., and* W. D. Halliburton, *M.D., F.R.S.*

In the communication on this subject published in the British Association Report last year we stated that cerebro-spinal fluid removed from cases of brain atrophy (particularly from cases of general paralysis of the insane) produces a fall of blood-pressure. From the similar result produced by choline we thought it possible that the toxic material derived from the disintegration of nervous tissues, and contained in the cerebro-spinal fluid, was choline also. We have now completed our chemical examination of the material, and proved that our supposition is correct.

The fall of blood-pressure which occurs is partly of cardiac origin, but its main cause is vascular dilatation in the splanchnic area. This was investigated by the use of Barnard's cardiometer, and by the use of air-plethysmographs applied to various organs. The intestinal oncometer used we owe to the ingenuity of Mr. A. Edmunds, B.Sc., who has described the instrument in the 'Journal of Physiology,' vol. xxii. 1898, p. 380.

By means of section of the spinal cord, and also by the use of large doses of nicotine, we have cut out the influence of the central nervous system, and of peripheral vaso-motor stations. Choline still produces, under these circumstances, the usual fall of blood-pressure, which is therefore due to the action of the poison on the neuro-muscular apparatus of the blood-vessels.

The allied alkaloid, neurine, produces somewhat different results, and is far more toxic. There is a primary fall in arterial pressure, mainly of cardiac origin; the slowing of the heart and deepening of respiration are very marked symptoms. Usually this is followed by a rise of pressure, due to constriction of peripheral blood-vessels. In some cases this latter phase is absent; and in some few cases, using very small doses, the second phase only occurs.

IV. *On the Myelination of Nerve Fibres. By* H. V. Anderson, *M.D.*

A systematic investigation of the peripheral nervous system of man, the cat, and the rabbit has been commenced to ascertain the relative progress and date of medullation of the various fibres of the cranial, spinal, and sympathetic nerves.

Afferent fibres have been distinguished from efferent by the use of the Wallerian method, and the number of afferent fibres in various somatic and sympathetic branches has been determined in kittens from a few days to several weeks old. At the same time the intra-spinal degeneration resulting from section of posterior roots in kittens of different ages has been traced by Marchi's method. By these observations an attempt has been made to divide the fibres of all the peripheral nerves into embryological systems, and to trace the distribution of each afferent and efferent system separately.

Several experiments have also been performed according to V. Gudden's method upon kittens and rabbits a few days old to determine—(1) the effect upon the development of a posterior root ganglion of section of the corresponding posterior roots or peripheral nerve trunk respectively; (2) the changes produced in certain posterior rootlets, spinal ganglia, and cells of the spinal cord by cutting many peripheral branches, each of which contains a relatively large proportion of fibres belonging to a given embryological system; (3) the effect upon the development of the fibres of the cervical sympathetic nerve of section of the nerve itself, or of branches of the superior cervical sympathetic ganglion; (4) the central origin of the fibres of the cervical sympathetic nerve by the atrophy of cells following section of the nerve in very early life; and (5) the alterations in the cells of a sympathetic ganglion resulting from section of its præ- or post-ganglionic fibres respectively.

I append a summary of some of the observations made:

The two systems of afferent fibres, which are the first to become medullated, are found to be common to both the somatic and sympathetic nerves, and to assume their fatty sheath before the efferent visceral fibres. The two afferent systems mentioned are distinguished from each other, not only by the considerable interval between the dates of their medullation, but also by the mode of their peripheral termination, the fibres of the earliest medullated system alone entering end-organs. The later medullated afferent fibres of both somatic and sympathetic nerves have not yet been fully investigated.

The efferent somatic fibres do not all become medullated at the same time, and certain embryological relations have been observed between certain cranial and spinal efferent fibres. The various visceral efferent fibres also develop their medulla at different dates.

Section of the posterior roots in very young animals has little, if any, effect upon the development of the corresponding posterior root ganglion, but section of the trunk of the nerve distal to the ganglion causes marked macroscopic and microscopic changes in the same duration of experiment, viz., about eight weeks. These results confirm the work of Lugaro upon the spinal ganglia of adult animals. In the second form of experiment obvious changes are found, also in the posterior roots, and it is possible by this method to connect certain posterior root fibres with given afferent nerves.

Early section of the cervical sympathetic nerve markedly hinders the development of the fibres of that nerve, and though some fibres become eventually medullated, they are small, and stain only a faint grey colour with osmic acid. In two kittens in which the internal carotid branches of the superior cervical sympathetic ganglion had been cut some days previously to the commencement of medullation in the cervical sympathetic nerve, I found later a smaller number of fibres medullated upon the cut side, and also many atrophied cells in the ganglion; but in a third experiment, in which longer time had elapsed since the section of the same branches, there was little, if any, difference in the two cervical sympathetic nerves. I have therefore made other experiments to decide what are the results following section of post-ganglionic fibres, but the experiments are not yet complete.

The section of the cervical sympathetic nerve in a young kitten appeared to have little, if any, effect upon the development of the superior cervical sympathetic ganglion.

In the cord of a kitten 120 days old, in which part of the cervical sympathetic nerve had been removed on the eighth day after birth, I found that the small cells in the lateral horn of the first, second, and third dorsal segments upon the cut side were very decidedly fewer in number than upon the uncut side. I have twice repeated this experiment, but the spinal cords have not yet been examined.

Some of my experiments by the atrophy method point clearly to the correctness of Mott's hypothesis, that cells of Clarke's column are connected with afferent nerve fibres supplying the lower limb.

A preliminary account of some of the observations made has been given in a thesis for the M.D. degree at Cambridge, and it is hoped that fuller details may soon be published.

V. *The Histology of Nerve Cells.* *By* GUSTAV MANN, *M.D.*

Over seventy different fixing methods were used, and chemically most diverse substances chosen so as to eliminate, if possible, all appearances due to arte facts. Reducing and oxidising, acid, neutral, and alkaline fixations, acid, neutral and alkaline stains, with reducing and oxidising substances added, were tried, and these results were obtained :—

(1) In all nerve cells there exists a peripheral zone, destitute of Nissl's bodies, and in this zone numerous fibrils and bundles of fibrils are seen.

(2) The zone-like origin of the axis cylinder is due to a special accumulation of the plasm constituting the peripheral zone.

(3) At the periphery of nerve cells the fibrils were not observed to branch.

(4) Bundles of fibrils run also through the centre of cells, past the nucleus, but the fibrils never come into contact with Nissl's bodies.

(5) In spinal ganglia two distinct bundles of fibrils may be distinguished, one corresponding to the peripheral and the other to the central process. These bundles are arranged in vortices.

(6) In central and peripheral multi-polar nerve-cells bundles of fibrils may be traced from dendritic processes to the axis-cylinder process, and from one dendritic process to another.

(7) The thorn-like excrescences seen in Golgi preparations are artefacts, caused by the potassium bichromate.

(8) The nodes of Ranvier are only crossed by the neuro-fibrils.

Photographs of wax models were taken, and the course of the fibrils traced in the following cells : Two giant cells of Malapterurus, motor cell from anterior horn of spinal cord of the ox, spinal ganglion cells of rabbit and dog, cell from spiral ganglion (cochlea) of guinea-pig, first giant cell of Amphioxus, sympathetic nerve-cell of rabbit. Photographs of nerve-cells of motor, olfactory, visual area from the dog's brain, showing fibrils, were also taken.

All attempts made as yet to obtain the substance which shows a great affinity for basic dyes, and is found in Nissl's bodies, were unsuccessful.

The Physiological Effects of Peptone and its Precursors when introduced into the Circulation.—Second Interim Report of a Committee, consisting of Professor E. A. SCHÄFER, *F.R.S.* (*Chairman*), Professor C. S. SHERRINGTON, *F.R.S.*, Professor R. W. BOYCE, *and* Professor W. H. THOMPSON (*Secretary*). (*Drawn up by the Secretary.*)

IN continuation of the above inquiry during the past year attention has chiefly been directed towards ascertaining the effects produced by albumoses and peptone upon the secretion of urine. The objects kept in view were threefold : (1) to determine the influence of the substances in question upon nitrogenous excretion at the kidney ; (2) to see if any important differences were manifested by the several substances when compared with each other ; (3) to ascertain to what extent the substances remained in or were excreted by the kidney from the animal body.

The products examined were (1) Witte's Peptone, (2) Proto-albumose, (3) Hetero-albumose, (4) Deutero-albumose, (5) Ampho-peptone, (6) Anti-peptone.

The following report is to be regarded as a statement of the year's work, and not as a finished research. The carrying out of the investigation was placed in the hands of the Secretary.

The method adopted was as follows :—Dogs were exclusively employed, the animals being anæsthetised with a mixture of chloroform and ether, preceded, except in a few of the earlier experiments, by a hypodermic injection of a solution of morphine. The dose of morphine employed was small, under two milligrammes per kilo. of body weight.

Cannulæ were placed in both ureters, and urine collected for definite periods before and after an injection of the substance employed. With the exception of hetero-albumose the substances were dissolved in physiological saline solution—·6 per cent. sodium chloride. The quantity of solvent employed was 4 c.c. per kilo. of body weight for animals below twelve kilos. Above this weight a maximum of 50 c.c. was adopted. Hetero-albumose was dissolved in 2 c.c. per kilo. of weak caustic soda solution (·2 per cent.).

The injection was made through a cannula placed in the external saphenous vein, and the substance introduced very slowly from a burette to avoid lowering of blood-pressure. The time occupied with the injection varied for the most part from fifteen to twenty minutes.

A record of blood-pressure was taken from the left carotid artery, and showed that the injection of the substances could be accomplished without appreciable lowering. The record was not continuous, but was taken at minute intervals during the period of injection. While the subsequent collection of urine proceeded, a record was taken every fifteen minutes.

As a rule, urine was collected for one hour, then the substance was injected, and urine collected for a second hour, likewise for a third, fourth, and also for a fifth.

The amount of total nitrogen and the quantity of urea were estimated in the different samples of the urine. That passed subsequent to the injection was also examined for the presence and amount of the albumose or peptone excreted.

The results, so far as ascertained at the date of this report, will be set forth under the following headings: (1) Influence on the quantity of urine secreted; (2) Influence on the amount of nitrogen and of urea produced; (3) Amount of peptone or albumose excreted.

I. *Influence on the Quantity of Urine.*

As will be seen in the following table, the introduction of the various substances was followed by a very large increase in the amount of urine secreted. The outflow reached its maximum in the second hour after the injection, and then gradually declined. But even at the end of four hours there was still, in the majority of cases, a decided increase, as compared with the outflow prior to the injection. A few experiments showed no increase.

TABLE I.—*Showing Quantities of Urine secreted per hour in cubic centimetres.*

(The injection was made at the end of the first hour, and extended over a period of 15 to 20 minutes.)

Exp.	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Weight of Dog in kilos.	Quantity of Fluid injected
		I.—*Witte's Peptone.*					
I.	5·5	60	102	53	29	11·8	50 c.c.
II.	14·5	77	124·5	56	36	14·5	50 „
		II. *Proto-albumose.*					
XV.	12	70	149	75	64	15·3	50 „
XVI.	10·5	*40m. 12·5* *20m. 25* 37·5	107·5	71	21·5	12·6	50 „
XX.	15	*30m. 33·5* *15m. 24* *15m. 25·5* 83	63·5	17·5	9	12·7	50 „
XXI.	22	*30m. 11·5* *30m. 9·75* 21·25	22	9	6	11·3	45 „
		III. *Hetero-albumose.*					
XXII.	13·5	6	Nil	*Dog died*	—	13·2	20 „ KoH. 2%
XXVII.	13	*45m. 33* *15m. 20* 53	90	33·5	15	8·3	20 „ NaOH. 2%
		IV. *Deutero-albumose.*					
XIII.	10	27·5	30·5	12	10	19·75	50 „
XIX.	10·5	15·0	60	39	29	14·0	50 „
XXXII.	3·5	22·75	13·25	6	—	6·3	24 „
		V. *Ampho-peptone.*					
III.	45	172	188	58	17·5	14·5	50 „
V.	7·3	49	85	56	19·5	10·5	50 „
VI.	3·75	11·25	8	4	—	8·0	40 „
XXIX.	5	*40m. 13·5* *20m. 12* 25·5	18·5	26·5	23·5	11·9	30 „

TABLE I.—*continued.*

Exp.	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Weight of Dog in kilos.	Quantity of Fluid injected
			VI. *Anti-peptone.*				
VII.	6	51	21·5	15·5	17	13·8	50 c.c.
VIII.	13·25	10	16	7·25	4·25	8·2	40 „
IX.	5·25	22	13	8	6	9·4	40 „
XVII.	8·66	38	27·5	18	—	15·0	50 „
XVIII.	18	78	170	75	35	16·0	50 „
XXVIII.	4·3	{*50m.10·5* *10m.3·5*} 14	17	11	8	11·3	30 „
XXX.	21	{*45m.22·5* *15m.14·25*} 36·75	93	40	12·5	8·1	25 „

The figures in italic in the column for the second hour show the amount of urine passed in the number of minutes indicated. The same applies, *mutatis mutandis*, to the subsequent tables.

No marked difference was manifested by the various substances in regard to the amount of diuresis produced, except that the proportion of instances where no increase of urine manifested itself was decidedly greatest in the case of the substance anti-peptone.

It is doubtful, however, if any stress can be laid upon diuretic influences, since control experiments made by injecting corresponding quantities of normal saline solution, without peptone or albumose, showed that a marked increase of urine, also reaching its maximum in the second hour afterwards, was produced by the solvent employed. This is illustrated in the following table :—

TABLE II.—*Showing the Influence of Normal Salt Solution upon the Quantity of Urine secreted (expressed in cubic centimetres).*

(The injection was made at the end of the first hour, and extended over a period of 4 to 8 minutes.)

Exp.	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Weight of Dog	Quantity injected per Kilo.	Total Quantity injected
1*	16	28	40	19·5	18·5	6·7 k.	4 c.c.	28 c.c.*
2	15	32	—	—	—	6·4 „	4 „	26 „
3	21	67	124	16	16	16·8 „	3 „	50 „
4	12	29	88	51	23	15 „	2 „	30 „
5	16·5	76	175	75	40	14·9 „	3·5 „	50 „
6	6·25	15·25	26·5	18·75	11	19·5 „	2·5 „	50 „
7	13	12·25	10	5·25	—	14·8 „	3 „	45 „

* In Experiment No. 1 an injection of 12 c.c. of caustic soda solution, 0·2% strength, was made at the end of the third hour.

The above effect, produced by small quantities of normal salt solution when introduced into the circulation, has proved to be a matter of very considerable interest, and forms the subject of a different research, which has arisen out of the present one.

Some observations were made on the reaction of the urine passed before and after the injection of the proteid. The majority of cases showed the normal urine to be alkaline. This alkaline was reduced to neutrality in the second or third hours or both, and gradually returned to a weakly alkaline condition, for the most part, before the close of the fifth hour.

II. *Influence on the Excretion of Nitrogen and of Urea.*

(*a*) *Percentage Output.*—The urine secreted in such large quantities proved to be very dilute, the percentage quantity of nitrogen and of urea being much reduced. The dilution ran almost parallel with the increase of urine, that of the third hour being the most dilute, and as the quantity of urine again reduced, it also became more concentrated. The following table illustrates this in detail so far as the percentage amount of total nitrogen is concerned.

TABLE III.—*Showing the Quantity of Nitrogen per cent. in the Urine Secreted (expressed in Grammes).*

Exp.	Weight of Dog	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5
I. *Witte's Peptone.*						
I.	11·8 k.	2·399	0·731	0·269	0·391	0·575
II.	14·5 „	1·677	0·986	0·319	0·591	0·795
II. *Proto-albumose.*						
XV.	15·3 „	5·023	1·299	0·406	0·580	0·655
XVI.	12·6 „	1·148	(*40 m.*) 1·4 (*20 m.*) 0·389	0·218	0·308	0·641
XX.	12·7 „	1·179	(*30 m.*) 0·742 (*15 m.*) 0·266 (*15 m.*) 0·220	0·298	0·77	1·512
XXI.	11·3 „	0·742	(*30 m.*) 0·491 (*30 m.*) 0·448	0·70	0·907	1·574
III. *Hetero-albumose.*						
XXII.	13·2 „	2·358	2·150	—	—	—
XXVII.	8·3 „	0·753	(*45 m.*) 0·512 (*15 m.*) 0·322	0·207	0·364	0·815
IV. *Deutero-albumose.*						
XIII.	19·75 „	7·767	2·380	1·166	3·091	3·954
XIX.	14 „	6·395	3·802	0·820	1·114	1·501
XXXII.	6·3 „	2·778	1·071	0·840	1·103	—
V. *Ampho-peptone.*						
III.	14·5 „	0·568	0·293	0·160	0·345	0·848
V.	10·5 „	3·214	0·728	0·290	0·283	0·896
VI.	8 „	1·714	1·294	0·790	0·269	—
XXIX.	11·9 „	1·512	(*40 m.*) 1·369 (*20 m.*) 0·322	0·339	0·409	0·577
VI. *Anti-peptone.*						
VII.	13·8 „	4·217	0·826	1·075	1·792	1·722
VIII.	8·2 „	2·142	2·710	1·753	1·319	2·302
IX.	9·4 „	4·990	1·495	1·454	1·960	2·654
XVII.	15 „	4·012	1·302	0·798	1·736	—
XVIII.	16 „	2·548	0·608	0·238	0·442	0·829
XXVIII.	11·3 „	3·920	(*50 m.*) 2·341 (*10 m.*) 1·176	0·999	1·316	1·288
XXX.	8·1 „	0·792	(*45 m.*) 0·703 (*15 m.*) 0·392	0·228	0·379	0·91

The percentage output of urea suffered a corresponding decrease, with subsequent return. It is not considered necessary to give a table.

(*b*) *Output Hour by Hour.*—Notwithstanding the dilute condition of the urine passed, it was found that the excretion of nitrogen and of urea, when measured hour by hour, suffered a decided increase as a result of the injection. This increase, with few exceptions, reached its maximum in the second hour (first after the injection). Part of the nitrogen increase of this hour, as will subsequently appear, is due to an excretion of proteid—albumose or peptone—with the urine. The increase of total nitrogen hour by hour is shown in the following table:—

TABLE IV.—*Showing the Quantity of Nitrogen excreted per Hour in the Urine (expressed in Grammes).*

Exp.	Weight of Dog	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Quantity of N. injected in grammes
I. *Witte's Peptone.*							
I.	11·8 k.	·1319	·4385	·2742	·2063	·1669	·0863
II.	14·5 „	·2432	·7067	·3388	·3314	·2763	·1078
II. *Proto-albumose.*							
XV.	15·3 „	·6027	·9094	·6049	·4347	·4193	·1565
XVI.	12·6 „	·1195	(*40 m.*) ·1750 (*20 m.*) ·0998	·2348	·2187	·1378	·1271
XX.	12·7 „	·1768	(*30 m.*) ·2486 (*15 m.*) ·0638 (*15 m.*) ·0560	·1893	·1347	·1361	·1271
XXI.	11·3 „	·1632	(*30 m.*) ·0567 (*30 m.*) ·0437	·154	·0816	·0944	·1174
III. *Hetero-albumose.*							
XXII.	13·2 „	·3183	·1290	—	—	—	—
XXVII.	8·3 „	·0979	(*45 m.*) ·1691 (*15 m.*) ·0644	·1865	·1219	·1222	—
IV. *Deutero-albumose.*							
XIII.	19·75 „	·5204	·6545	·3455	·3704	·3954	·2012
XIX.	14 „	·4477	·5704	·4922	·4346	·4352	·1408
XXXII.	6·3 „	·0972	·2434	·1113	·0662	—	not determined as yet
V. *Ampho-peptone.*							
III.	14·5 „	·2556	·5014	·3000	·2072	·1485	·1098
V.	10·5 „	·2357	·3567	·2463	·1584	·1747	·1483
VI.	8 „	·0651	·1455	·0632	·1075	—	·1342
XXIX.	11·9 „	·0756	(*40 m.*) ·1848 (*20 m.*) ·0386	·0727	·1083	·1355	·1618
VI. *Anti-peptone.*							
VII.	13·8 „	·2530	·4213	·2312	·2777	·2927	·1998
VIII.	8·2 „	·2838	·2710	·2804	·0956	·0978	·1427
IX.	9·4 „	·2619	·3289	·1890	·1568	·1593	·1427
XVII.	15 „	·3475	·4947	·2194	·3125	—	·2140
XVIII.	16 „	·3058	·4739	·4046	·3318	·2901	·2283
XXVIII.	11·3 „	·1698	(*50 m.*) ·2458 (*10 m.*) ·0412	·1699	·1448	·1030	·1712
XXX.	8·1 „	·1664	(*45 m.*) ·1581 (*15 m.*) ·0559	·2122	·1518	·1137	·1156

But the urea—estimated by the method of Mörner and Sjögvist, which avoided the inclusion of any of the proteid—also showed a parallel increase, reaching its maximum likewise in the urine of the second hour. This is made clear by the following table. Moreover, it will be seen on examining the last column of this table, that the proteid injected could not have supplied nearly enough nitrogen to make up the increase of the second hour alone, to say nothing of the lesser increase shown in the following hours :—

TABLE V.—*Showing the Quantity of Urea excreted per Hour (expressed as Nitrogen in Grammes.)*

Exp.	Weight of Dog	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Quantity of N. injected
			I. *Witte's Peptone.*				
I.	11·8 k.	—	·3679	·2285	·1751	·1494	·0863
II.	14·5 „	·2123	·5954	·2859	·3025	·2500	·1078
			II. *Proto-albumose.*				
XV.	15·3 „	·5350	·7722	·5507	·3885	·3655	·1565
XVI.	12·6 „	·0991	(*40m.*) ·1159 (*20m.*) ·0847	·2062	·1809	·1198	·1271
XX.	12·7 „	·1453	(*30m.*) ·1801 (*15m.*) ·0538 (*15m.*) ·0518	·1618	·1137	·1172	·1271
XXI.	11·3 „	·1198	(*30m.*) ·0322 (*30m.*) ·0269	·1185	·0660	·0706	·1174
			III. *Hetero-albumose.*				
XXII.	13·2 „	·2569	·0934	—	—	—	—
XXVIII.	8·3 „	·0671	(*45m.*) ·1247 (*15m.*) ·0596	·1638	·1079	·0937	—
			IV. *Deutero-albumose.*				
XIII.	19·75 „	·4499	·5159	·3177	·3105	·2929	·2012
XIX.	14 „	·3853	·4536	·4284	·3636	·3735	·1408
XXII.	6·3 „	·0747	·1962	·0976	·0544	—	not determined
			V. *Ampho-peptone.*				
III.	14·5 „	·2268	·4238	·2290	·1552	·1151	·1098
V.	10·5 „	·2002	·2764	·2249	·1388	·1554	·1483
VI.	8 „	·0443	·0822	·0426	·0766	—	·1342
XXIX.	11·9 „	·0533	(*40m.*) ·1092 (*20m.*) ·0275	·0414	·0846	·1079	·1618
			VI. *Anti-peptone.*				
VII.	13·8 „	·2235	·3510	·2020	·2408	·2570	·1998
VIII.	8·2 „	·2307	·1915	·2253	·0711	·0714	·1427
IX.	9·4 „	·2252	·2661	·1288	·1366	·1398	·1427
XVII.	15 „	·3108	·3910	·1911	·2788	—	·2140
XVIII.	16 „	·2439	·3691	·3379	·2667	·2352	·2283
XXVIII.	11·3 „	·1246	(*50m.*) ·1940 (*10m.*) ·0356	·1418	·1138	·0806	·1712
XXX.	8·1 „	·1385	(*45m.*) ·1164 (*15m.*) ·0487	·1849	·1277	·0973	·1156

The marked increase in the hourly output of total nitrogen and of urea, beyond that contributed by the proteid injected, cannot, however, be solely attributed to any influence which the substances employed might be supposed to exert upon nitrogenous metabolism. A similar though less marked influence is shown after the injection of normal salt solution alone. This is expressed in the following table, where it will be observed that the maximum effect is likewise shown in the second hour :—

TABLE VI.—*Showing the Effects of Normal Salt Solution on the Nitrogen excreted Hour by Hour (expressed in Grammes).*

(N.B.—The injection of normal saline was made at the end of the first hour.)

Exp. No.	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Weight of Dog	Quantity injected per kilo.	Total quantity injected
1*	·1115	·0956	·0857	·0551	·0767	6·7 k.	4 c.c.	28 c.c.
2	·1050	·1204	—	—	—	6·4 "	4 "	26 "
3	·1570	·2082	·2066	·0923	·1120	16·8 "	3 "	50 "
4	·1754	·3021	·2489	·2113	·2074	15 "	2 "	30 "
5	·3497	·5533	·3748	·2583	·2285	14·9 "	3·5 "	50 "
6	·2481	·3181	·2378	·2677	·2482	19·5 "	2·5 "	50 "
7	Nitrogen not determined					14·8 "	3 "	45 "

* In Experiment No. 1, an injection of 12 c.c. of caustic soda solution, 0·2 per cent. strength, was made at the end of the third hour. A mixture of morphine and atropine was employed by mistake to inject this dog.

Observations upon body temperature, taken per rectum, showed that a steady rise occurred after the injection was made. The rise generally appeared towards the end of the first hour after injecting, and for the most part continued to increase till the end of the experiment.

Thus, in Experiment XXI. (proto-albumose) the temperatures were as follows:—Normal 37·4°C.; at end of first hour 37° C—the injection was then made; at the end of the second hour, temperature 37° C.; at the end of the third 37·8; at end of fourth 38° C. This was not the highest temperature attained by any means; the maximum in several experiments reached 40° C., and in one it reached 41·2° C.

This rise of temperature occurred even when the fluid injected was previously sterilised by boiling, and notwithstanding precautions to keep the animals cool while on the table. A similar rise of temperature also took place when sterilised normal salt solution was injected. In some of the experiments the maximum temperature was attained in the third hour (second after injection), followed by a return towards normal in the subsequent hours.

III. *Amount of Peptone or Albumose excreted in the Urine.*

This was regarded as an important point to determine. It bears upon the question as to whether the substances under observation are to be considered as wholly foreign to the blood, or to be looked upon in the same light as dextrose, which is excreted by the kidneys only when the amount in circulation exceeds a certain point.

Previous experimenters had arrived at different conclusions with regard to the reappearance of peptone at all in the urine after injection into the circulation.

Schmidt-Mülheim,[1] who first studied the question, used large doses, and obtained suppression of urine lasting from twenty to ninety minutes. In the urine subsequently passed he detected no peptone. *Fano*[2] obtained similar results, as did also *Grosjean*[3] many years later, both likewise employing large doses. *Hofmeister*,[4] meanwhile, had however shown that these substances reappeared very quickly in the urine, and devised an ingenious method, based upon the depth of tint given by the biuret reaction, for estimating how much proteid became excreted. He corrected his estimation by the use of the polarimeter, and came to the conclusion that 66 to 80 per cent. of the peptone introduced was expelled from the body within twenty-four hours. Owing to difficulties in the employment of these methods, neither can be regarded as capable of yielding accurate results. This is, indeed, admitted by the author, and, as we shall see, the figures he arrived at are a good deal too high.

In the earlier experiments of this research, no other sufficiently reliable method of estimating the amount of peptone or albumose excreted was apparent. From the first, it was seen that the substance appeared only in the urine secreted during the hour immediately following the injection, and from the depth of the biuret tint it was obvious that not nearly all the proteid injected came out again.

On more close examination it was found that the output of proteid was, as a rule, confined to the urine of the first forty or forty-five minutes succeeding the injection. It was also seen, on comparing the urea nitrogen of this period with the total nitrogen of the same time (which included that of the excreted proteid), that the whole difference was considerably less than the nitrogen injected. But this difference included the nitrogen of other compounds than urea, which I shall subsequently call 'extractive' nitrogen. If a safe deduction, to represent the 'extractive' nitrogen, could be made, then we should have ascertained the amount of proteid-nitrogen which reappeared. Such a deduction was arrived at by basing a calculation on the 'extractive' nitrogen of the urine secreted immediately after the peptone or albumose ceased to come out. When this was accomplished in forty to forty-five minutes, the urine of the remaining part of this hour furnished the basis of calculation. The same principle was, however, applied to many of the earlier experiments. The deduction in these cases was calculated on the 'extractive' nitrogen of the third hour, and the subtraction made from the 'difference' nitrogen of the whole of the preceding hour.

In both cases the urine which furnished the basis of calculation was more dilute than that of the peptone (or albumose) excretion-period; consequently, the amount deducted is safe, in the sense of being under rather than over the mark.

In the following table, which gives a succinct statement of the facts

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[1] Schmidt-Mülheim, 'Beiträge zur Kenntniss des Peptons und seiner Physiologischen Bedeutung,' *Archiv f. Physiolog*, 1880, p. 33.

[2] Fano, 'Das Verhalten des Peptons und Tryptons gegen Blut und Lymphe,' *Archiv f. Physiolog*, 1881, p. 277.

[3] Grosjean, 'Recherches sur l'Action physiologique de la Propeptone et de la Peptone,' *Travail du Lab. de Physiologie de l'Univ. de Liège*, tome iv. 1891–92. Also *Archiv. de Biologie*, 1892, xi. p. 381.

[4] Hofmeister, *Zeitschrift f. Physiologische Chemie*, 1881, p. 127.

arrived at, the earlier experiments (where the calculations are based on what I have called the 'difference' nitrogen of the whole second hour) are indicated by an asterisk :—

TABLE VII.—*Showing the Amount of Proteid excreted (expressed in Grammes.)*

Exp.	Weight of Dog	Nitrogen injected	Proteid N. + extractive N. of 2nd hour	Allowance for Extractive N.	Net. Proteid N. excreted	Per cent. of Proteid excreted	Period on which Calculation is based
I. *Witte's Peptone*: not estimated, data insufficient. The same applies to Hetero-albumose.							
II. *Proto-albumose.* Average 47 per cent.							
*XV.	15 3 k.	·1565	·1372	·0645	·0727	46·45	One hour
XVI.	12·6 „	·1271	·0591	·0076	·0515	40·52	40 min.
XX.	12·7 „	·1271	·0785	·0094	·0691	54·37	45 min.
III. *Deutero-albumose.* Average (?)							
*XIII.	19·75 „	·2012	·1386	·0250	·1136	56·46	One hour (urine contd. albumen)
*XIX.	14 „	·1408	·1868	·0159	·1009	71·65	One hour
XXXII.	6·3 „	—	—	—	—	—	Not as yet estimated
IV. *Ampho-peptone.* Average 39 per cent.							
*V.	10·5 „	·1483	·0803	·0123	·0680	45·86	One hour
*VI.	8 „	·1342	·0633	·0206	·0427	31·82	„ „
XXIX.	11·9 „	·1618	·0756	·0125	·0631	38·99	40 min.
V. *Anti-peptone.* Average 27·5 per cent.							
*VIII.	8·2 „	·1427	·0795	·0344	·0451	31·60	One hour
*XVIII.	16 „	·2283	·1048	·0306	·0742	32·11	„ „
XXVIII.	11·3 „	·1712	·0518	·0168	·0350	20·44	50 min.
XXX.	8·1 „	·1156	·0417	·0114	·0303	26·21	45 „

The average of amounts of excreted proteid are, for proto-albumose, 47 per cent. for deutero-albumose (not calculated); for ampho-peptone, 39 per cent. ; for anti-peptone, 27·5 per cent. But even these averages are considerably too high, for two reasons : first, because they include experiments where the calculation is made on a longer period than the actual 'peptone'-excretion period ; and, secondly, because it is fairly certain that the deduction made, for 'extractive' nitrogen, even in the later experiments, is too low. If we examine Table VI., which gives the effect of normal salt solution upon the output of nitrogen, we shall see that the augmentation caused by it is greatest in the second hour, and the same applies to urea. Consequently, it is believed that a much greater, probably twice as great, deduction might safely be made for the 'extractive' nitrogen of the excretion period in the peptone and albumose experiments. This would considerably reduce the proportion throughout, below that shown in Table VII.

The experiments, therefore, would make it appear probable that peptones and albumoses are not wholly foreign substances to the circulating blood. This conclusion cannot, however, be pushed too far, since it is uncertain to what extent any given substance introduced into the circulation is again recoverable from the urine, nor is it certain how long the substances in question retain their identity after being so introduced.

It is significant, however, in the light of Siegfried's work, that anti-peptone remains in the system to a much greater extent than any of the other substances employed. Some of the experiments were performed with anti-peptone kindly supplied by Professor Siegfried, for which best thanks are here expressed.

The research is still in progress.

Fertilisation in Phæophyceæ.—Report of the Committee, consisting of Professor J. B. FARMER (*Chairman*), Professor R. W. PHILLIPS (*Secretary*), Professor F. O. BOWER, *and* Professor HARVEY GIBSON.

THE Committee beg to report that they have again devoted the whole of the 15*l.* placed at their disposal to aiding Mr. J. Lloyd Williams in the prosecution of his researches on the *Fucaceæ* and *Dictyotaceæ*. Mr. Williams's interesting discovery of the occurrence of motile antherozoids in *Dictyota* and *Taonia* was announced to the Botanical Section at the meeting at Toronto. A full description of these antherozoids has been published in the 'Annals of Botany' (December 1897).

The following is a brief summary of the points to which Mr. Williams has been directing his attention more particularly :—

(1) *The Fertilization and Cytology of Ascophyllum and Fucus.*—This investigation is in continuation of a joint research by Professor Farmer and Mr. Williams on these genera, the results of which are in course of publication in the 'Transactions of the Royal Society.'

(2) *The Process of Fertilization in Halidrys.*—Certain remarkable phenomena accompanying the act of fertilization have been observed in *Halidrys Siliquosa*, a description of which will appear in the paper referred to above.

(3) *The Zones of Growth and Periods of Maturation of the Sexual Products in Fucaceæ.*—Mr. Williams has subjected all the species of Fucaceæ in the Menai Straits to a careful and continuous examination, and his observations add greatly to our knowledge of what may be called the Natural History of these species.

(4) *The Examination of the Sexual Cells in Dictyota and Taonia.*—The discovery of motility in the male sexual cells in these genera has already been referred to. Further, the process of fertilization has now been observed, the occurrence of parthenogenetic germination of the oospheres confirmed, and an interesting discovery of a marked periodicity in the maturation and liberation of the sexual cells in *Dictyota* has been made. Upon this subject the Committee are glad to learn Mr. Williams hopes to submit a paper to the Section at the forthcoming meeting at Bristol.

Since the last meeting of the Association, Mr. Williams has been appointed Assistant Lecturer and Demonstrator in Botany at the University College of North Wales, Bangor, and he is thus favourably situated by residence at the seaside for the prosecution of the studies which he has on hand. The Committee would earnestly recommend the continuation of the grant for another year, and, convinced that interesting results will accrue to science as a result of Mr. Williams's investigations, they would propose to devote it again to assisting him in his work.

INTERNATIONAL CONFERENCE

ON

TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY.

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TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY.

President of the Conference—Professor A. W. Rücker, M.A., D.Sc., Sec. R.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

The President of the Section of Mathematics and Physics has already expressed the pleasure with which British physicists welcome the distinguished band of visitors who have assembled to take part in the International Conference on Terrestrial Magnetism. None join in that welcome with more cordiality than those who are especially interested in the science with which the Conference will be occupied. To us it is a source both of gratification and pride that the International Committee, to whose action this meeting is due, should have allowed us to play the part of hosts to the eminent men from many lands who have responded to their call. Some whom we would gladly have seen here, but who have been prevented from attending by various causes, have nevertheless shown the interest which they take in our proceedings by sending written communications. Thus our meeting is as fully representative as we could have hoped.

It may be interesting to those who are unaware of the fact if I remind the Conference that this is not the first occasion on which students of Terrestrial Magnetism have taken counsel together during a meeting of the British Association.

Fifty-four years ago the then President of the Association, the Very Rev. George Peacock, Dean of Ely, stated in his address that the period was drawing to an end for which a series of magnetic observatories had been established by international co-operation. 'Six observatories,' he stated,[1] 'were established, under the zealous direction of M. Kupffer, in different parts of the vast empire of Russia, the only country, let me add, which has established a permanent physical observatory. The American Government instituted three others, at Boston, Philadelphia, and Washington; two were established by the East India Company, at Simla and Singapore; from every part of Europe, and even from Algiers, offers of co-operation were made.' The observations thus provided for were to be carried out for three years only, but, as nearly the whole of that time was spent in preparation, the period was doubled. When the term thus

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[1] *Brit. Assoc. Rep.*, 1844, p. xliv.

fixed drew to an end, the question arose as to whether it was desirable to extend it further, and M. Kupffer (Director-General of the Russian System of Magnetic and Meteorological Observations) addressed a letter to Colonel (afterwards Sir Edward) Sabine, suggesting the propriety of summoning a magnetic congress to be held at the next meeting of the British Association.

In accordance with that suggestion the Congress was held during the meeting of the Association at Cambridge in 1845. The number of distinguished foreigners who attended in person was considerable, in spite of the difficulties of travel fifty years ago. Amongst those who were present was M. Kupffer; Dr. Erman, of Berlin, the celebrated circumnavigator and meteorologist; Baron von Senftenberg, the founder of the Astronomical and Meteorological Observatory of Senftenberg, in Bohemia; M. Kreil, the Director of the Imperial Observatory at Prague; Dr. von Boguslawski, the Director of the Royal Prussian Observatory at Breslau; Herr Dove, Professor of Physics in the University of Berlin; and Baron von Waltershausen, a gentleman who had taken part in the magnetic observations of Gauss and Weber at Göttingen, and had executed a magnetic survey of portions of Italy and Sicily. In addition to these a number of well-known British men of science were invited to be present, amongst whom I need only mention the Marquis of Northampton (President of the Royal Society), Sabine, Sir John Herschel, Lloyd, Airy, Brown, and Sir James Ross, then recently returned from his celebrated expedition to the Antarctic Seas. Letters were also received from Wilhelm Weber, Gauss, Loomis, Lamont, Quetelet, Von Humboldt, and others.

The principal question which this conference had to decide was whether 'the combined system of British and foreign co-operation for the investigation of magnetic and meteorological phenomena, which [had then] been five years in progress, must be broken up.'[1] I will not trouble you with a recapitulation of the recommendations of the Congress, some of which have been carried out, while others have not yet been realised; but one resolution will, I am sure, so exactly express your own sentiments that I venture to quote it, viz.: 'That, the cordial co-operation which has hitherto prevailed between the British and foreign magnetic and meteorological observatories having produced the most important results, and being considered by us as absolutely essential to the success of the great system of combined observation which has been undertaken, it is earnestly recommended that the same spirit of co-operation should continue to prevail.' Whatever changes half a century may have wrought in the problems which press upon magneticians, and in the difficulties which confront them, there can be no doubt that they are still of the same spirit as that in which this resolution was framed.

It is true that we sometimes meet with the objection that international conferences of all kinds are now too numerous, and that their decisions, from their very number and complexity, cease to attract attention or to command respect. Admitting that this objection is not without weight, it may be answered by two remarks. The closer union between scientific workers in different countries which these meetings encourage, the strengthening of the ties of intellectual sympathy by those of personal friendship, are in themselves good. It is surely a hopeful omen that science, as she reaches her maturity, forgets or ignores the political and

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[1] *Brit. Assoc. Rep.*, 1845, p. 69.

geographical boundaries which sometimes seemed so important in her youth, and that workers for the common good are more and more learning that it is good to work in common.

But there are special and cogent reasons why the science of Terrestrial Magnetism should be cosmopolitan. The advance of some sciences is most easily achieved by the methods of guerilla warfare. In a hundred different laboratories widely separated workers plan independent attacks on Nature. In different Universities and Colleges little groups are devising stratagems and arranging ambuscades in the hope of wresting from our great opponent some of the treasures which she yields only to the violent who take them by force. But for those who would unravel the causes of the mysterious movements of the compass needle concerted action is essential. They cannot, indeed, dispense with individual initiative, or with the leadership of genius, but I think that all would agree that there is urgent need for more perfect organisation, for an authority which can decide not only what to do, but what to leave undone.

The advance of the science of Terrestrial Magnetism must depend upon the establishment, the maintenance, and the utilisation of the records of observatories. The bulk of the material to be dealt with must in any case be vast, and every needless addition to it, every obstacle in the way of its being readily comprehended and easily used, is a drawback which proper organisation should prevent.

Thus it is wasteful to devote to the multiplication of observatories, in regions of which we know much, energy and funds which would be invaluable if applied to districts of which we know little or nothing. I take some credit to myself in that within the last few months I have assisted in checking well-intended but mistaken proposals to add to the number of the magnetic observatories which we already possess in this country.

Again, it is desirable that the records of the observations should be so published as to be ready for application to the problems the solution of which they are intended to subserve, and that the individual worker should not be harassed by petty differences in the methods of presentment, which often entail on him labour too enormous to be faced. On this point something has already been done by international co-operation, and we may hope that this meeting will do much to complete the task.

Lastly, there are many investigations which are now undertaken independently at irregular intervals which would be far more useful if planned in common. Thus, there has of late been a great outburst of energy in Europe devoted to magnetic surveys more detailed than have ever before been accomplished. Is it too much to hope that when the time comes for these to be repeated they may be carried out simultaneously, and reduced by the same methods, so that we may have a magnetic map of Europe in which no uncertainty as to the accuracy of details is introduced by the necessity for correcting for the secular change over long intervals of time?

Taking it for granted, then, that international co-operation is desirable for purposes such as these, I come next to the question of the nature of the machinery by which it shall be secured. And here I may at once state that the arrangements under which we are meeting to-day are in some respects abnormal, and that plans for the future will have to be formally or informally considered before we part. Meanwhile, it is desirable that I should state precisely the circumstances which have brought us together.

The last meeting of the International Meteorological Conference was held in Paris in September 1896. It was attended by several men of science specially interested in Terrestrial Magnetism, and, perhaps on this account, a new departure was taken by the International Committee, in the appointment of a 'Permanent Committee for Magnetism and Atmospheric Electricity,' to which certain specific questions were referred. Eight gentlemen were nominated as members of this Committee, with power to add to their number. We in turn co-opted eight other magneticians, taking care that as far as possible all countries in which Terrestrial Magnetism is specially studied should be represented. About the same time, and, as I believe, in ignorance of the establishment of this Committee, a suggestion for the assembling of an International Conference on Terrestrial Magnetism was made in the Journal of that name by Professor Arthur Schuster. It appeared to me and to Professor Schuster himself that it would be a great pity if this suggestion resulted in the establishment of a rival organisation, and I at once submitted to the Committee the question whether, in their opinion, it was desirable that we ourselves should take the responsibility of summoning an International meeting, with the view of obtaining a wide discussion of the points submitted to us by the Meteorological Conference. This suggestion was approved, and, as the British Association was willing to allow us to organise the conference as a branch of Section A (Mathematics and Physics), to undertake the expense of sending out the necessary notices, to print our papers in its Report, and to extend to foreign members of the Conference all the privileges of foreign members of the Association, it was also determined that so hospitable an invitation should be accepted with the gratitude it deserved. But although the main result has been achieved, and a representative gathering of magneticians has assembled in Bristol, it cannot be denied that our relations to the various bodies with which we are connected are somewhat complicated, and that our constitution is devoid both of simplicity and symmetry. I take it that these facts are signs of health and vigour rather than symptoms of decay. Terrestrial Magnetism has been attracting far more attention of late years than in the not very distant past. The necessity for meeting, for common action, for common publication has been forced upon us. We have cared more for meeting than for the terms on which we were to meet, more for acting together than for drawing up an elaborate deed of partnership, more for the promotion of science than for a flawless paper constitution. Thus, and in my opinion most wisely, we have sought to attain our ends, not by starting a brand new International Association, but by making use of machinery which is already in existence, which has stood the test of time, and is, as I believe, capable of being put to new uses in meeting our wants and supplying our deficiencies.

I confess, however, that in this arrangement we have been compelled to pay scant attention to the simplicity and even to the logical consistency of our schemes. We are an International Conference on special subjects —Terrestrial Magnetism and Atmospheric Electricity—summoned by a Committee owing its authority and bound to report to another International Conference of wider scope, which regards our sciences as branches of Meteorology.

On the other hand, this Committee is for the moment a part of the Committee of the Section of Mathematics and Physics of the British Association, though it retains its right of separate meeting, more especially for the discussion of its report to the International Meteorological Conference. It is evident that here there is plenty of opportunity for collision between rival authorities, for confusion between conflicting jurisdictions; but to all questions as to the precise limits of authority and jurisdiction it is sufficient to reply in the most general terms. The whole of the arrangements are temporary, to meet an immediate pressing need. The work of the Conference will be conducted like that of a Department of the British Association. The members of the International Committee will act as the Committee of the Department, but some of their work will be done on the General Committee of Section A, of which other magneticians will also be members. Should it be necessary, they will hold some separate meetings, and some such meetings will certainly be necessary to discuss their report to the International Meteorological Conference. These general regulations will probably suffice for all practical purposes. If cases occur which they do not cover, we must deal with them as they arise.

With regard to the future, I do not propose to lay before you any detailed scheme, but in discussing the matter among ourselves the following principles should, in my opinion, be adhered to. The International Meteorological Conference has held a number of successful meetings. I believe that I am correct in saying that the right to attend that Conference was at first confined to those who were officially connected with Meteorological and Magnetic observatories, but that of late invitations have been more widely distributed. If the authorities of that Conference see their way to inviting in future most or all of those who are known to be specially interested in Terrestrial Magnetism, I do not see why the Magnetic Conference, which would then be constituted once in five years, should not meet all our requirements. If, however, additional meetings are necessary, I would urge that they should be held in turn in different countries, and, if possible, in connection with existing societies which play elsewhere the part taken by the British Association in this country.

That a permanent committee should be established is essential, and the mode of appointing this body must no doubt be considered, but I hope that in the course of the next few days the committee may be able to discuss the whole question, and that when the next meeting of the Meteorological Conference takes place we may be able to lay before the Committee suggestions which may lead to the foundation of an International Magnetic Association on a stable and permanent basis.

Another matter of great importance is the maintenance of an international journal devoted to Terrestrial Magnetism. This we now possess, thanks to the energy of Dr. Bauer, and I feel sure that all present will agree that such a means of intercommunication is invaluable. I believe, however, that the enterprise is threatened with financial dangers, and I desire to take this opportunity of urging all those who are interested in its success to do what they can to support it by increasing the circulation. There is every reason for making more use of a common journal. The records of the observatories are necessarily so bulky, that anyone who desires to obtain the facts as to the magnetic state of the earth at any given time must collect or consult a large library of quarto volumes, in some of which the magnetic facts are mingled with data interesting chiefly to the meteorologist or astronomer. It is no doubt essential that an account of all the work done at each observatory should be published in a collected form, and that full details of the magnetic observations should be given; but for many, nay, for most, purposes, those who use the records will require only final results; the means of the various elements for the year, for each month, or for any other period which may hereafter be adopted, and the diurnal variation, are in general wanted, rather than the hourly values. If these means could be published together, once a year, an enormous boon would be conferred upon magneticians. For special purposes the theorist will have to test his views by reference to the results published in their fullest detail; but it would be no slight gain if the more salient facts could be compared by being placed side by side in the same journal. One advantage such a system would unquestionably possess. It would impress upon the authorities of the observatories the necessity for adhering to a common form of publication.

Some small beginnings have already been made. The Kew Observatory Committee now publish in the 'Proceedings' of the Royal Society the annual means of the elements recorded by all the observatories which send their publications to Kew. By comparing two of these tables, the secular change can at once be determined. But the system is capable of extension, not merely to the normal values of the elements, but to disturbances. By common agreement, Greenwich and Parc St. Maur publish in each year the records of the same magnetic storms. If this agreement could be extended, and if the facts thus selected were brought into juxtaposition, we might hope for a fuller and more instructive analysis than is at present usual.

Turning from questions of organisation, the primary business of our conference will be to discuss four questions submitted to our Committee by the International Meteorological Conference.

The first two of these refer to the methods for calculating and publishing the monthly means of the magnetic elements which should, in our opinion, be adopted. I will not anticipate the discussion which will take place on these points, except to say that it will be necessary to bear in mind not only what is desirable but also what is practicable in view of the resources at the disposal of the directors of the various magnetic observatories.

Another question deals with the relative merits of long and short magnets, and on this point we shall have the advantage of hearing a report on the subject by M. Mascart.

Lastly, there is a very important proposal for the establishment of temporary magnetic observatories at certain specified places. General Rykatcheff and Professor von Bezold present an excellent report on this subject, and I will only remind you, that whereas the accuracy of the mathematical expression of the magnetic state of the earth's surface depends entirely on the number and position of the spots at which the magnetic elements are accurately known, the establishment of temporary observatories will be a costly undertaking, for the carrying out of which all the resources at the disposal of international science will have to be employed.

Another point of considerable practical importance will also be brought before us. The rapid extension of electrical railways and tramways is a serious menace to magnetic observatories. From all parts of the world we hear of observatories ruined or threatened by the invasion of the electrical engineer. Toronto and Washington have already succumbed, Potsdam, Parc St. Maur, Greenwich, and Kew are besieged, and the issue largely depends upon whether these great national observatories can or cannot make good their defence.

It seems to be a law of Nature, ruling alike the human race and the humblest microbe, that the products of an organism are fatal to itself. The pessimist might infer that we are in presence of another instance of the universality of the application of this law, and that pure science is threatened by the very success of its practical applications. The smoke of our cities blots the stars from the vision of the astronomer, who, like the anchorites of old, flies from the world to mountains and desert places. It is only in the small hours of the morning when

> 'Save pale recluse, for knowledge seeking,
> All mortal things to sleep are given,'

that the physicist can escape from the tremors of the traffic of a great town.

Civilisation as it spreads by aid of the means that science has placed at its disposal is destroying records, and obliterating boundaries by the study of which the anthropologist and the biologist might have read far back into the history of our race. And now in turn the science of Terrestrial Magnetism, which, on the one hand, is forging another link to connect the sun and earth, and, on the other, is penetrating within the surface of the globe to depths beyond the ken of the geologist, is threatened by the artificial earth currents of the electric railway.

That the crisis is serious there can be no doubt, but I will only anticipate the fuller discussion which will take place by stating that magneticians, in common with the rest of the world, recognise the great benefit which electric traction confers upon the community at large. We are not so foolish as to desire to embark on a crusade against a great industrial improvement of which science may well be proud; on the other hand, we must hold fast to the position that provision for the conveniences which are immediately appreciated by the public should be made with as little damage as possible to those studies which are not less for the ultimate benefit of the race.

Had science, when the use of coal was introduced, been sufficiently advanced to devise means for smokeless combustion, an evil which now in more senses than one darkens the lives of the inhabitants of our great towns might have been prevented from attaining its present gigantic proportions.

We are now at the beginning of another industrial epoch, which may indeed, if power is transmitted from a distance on a large scale, brighten our skies, but which threatens to saturate the earth beneath us with electric currents. That these may interfere with the general comfort is evident from the injury which has been done to underground pipes at Washington and elsewhere. The construction of a powerful electrical railway in the immediate neighbourhood of the laboratories of a college would interfere with its efficiency, and make it impossible to perform experiments of certain types. In such a case, however, something could be done by arranging the experiments to suit the conditions under which they would have to be performed. But in the case of a magnetic observatory no such protective measures are possible. The very object of the observatory is to measure the earth's field, and if that field is artificially altered no modification of the methods of measurement, however ingenious, can overcome this fundamental defect. I am glad to take this opportunity of acknowledging that both the danger to pure science and the necessity for obviating it have been acknowledged by those who are chiefly interested in the technical applications of science; and in particular that one of the principal technical journals, the 'Electrician,' has supported the view that industry can and ought to respect the necessities of research.

If, however, there be any who are inclined to ask whether the careful study of Terrestrial Magnetism has led or is leading to any definite results, or whether we are not merely adding to the lumber of the world by piling up observations from which no deductions are drawn, we may answer that, though the fundamental secret of Terrestrial Magnetism is still undiscovered, the science is progressing. In the presence of several of the most active workers I will not enter into a detailed discussion of the tasks to which they are devoting themselves ; I will only ask that the doubter should compare a good summary of the state of the science of Terrestrial Magnetism written fifteen or twenty years ago, such as that contained in the article by Balfour Stewart in the 'Encyclopædia Britannica,' with what would be written on the same subject to-day. Additions would have to be made to the descriptions of the instruments employed, to the discussion of the theory of the diurnal and secular change, while such questions as the reality of earth-air currents and the tracing of loci of local disturbance have only been dealt with effectively in very recent times. When, too, we compare the older models of the magnetic state of the earth with that devised by Mr. Henry Wilde we cannot but admit not only that a great advance has been made in forming a simple diagram of the magnetic state of the earth, but that it is possible that the model contains a very pregnant hint as to the physical construction of the earth as a magnetic body.

The fact that Mr. Wilde has imitated the declination and dip with remarkable accuracy all over the surface of the earth by means of a simple arrangement of electrical currents, and by coating the oceans with thin sheet iron, has not attracted the attention it deserves. Whether the physical cause thus suggested be due to the greater depth to which the underground isothermals penetrate below oceans, the bottoms of which are always cold, or whether the geological nature of the rocks is different below the great depressions and elevations of the earth's surface, respectively may be open to question, but I am persuaded that the matter should be more fully investigated.

In conclusion, let me once more revert to the points on which I dwelt at the beginning of this brief address. We meet with the confidence of men who know that their science is progressing, but with the mingled hopes and fears of those who still have to deal with the great unsolved problem of the causes of Terrestrial Magnetism and of its manifold fluctuations. This solution will be most easily attained if we are not merely content to collect facts, but if we so arrange that they shall be easily dealt with. To observe is our first duty, to organise our second, and if these be fulfilled we may hope that a theory of terrestrial magnetism will in the future crown the efforts not merely of him on whom the first glimpse of the truth may flash, but of the international co-operation which has, by way of preparation, made 'the crooked straight and the rough places plain.'

The following Papers were read:—

1. *On the Relative Advantages of Long and Short Magnets.*
By Professor E. MASCART.[1]

[Ordered by the General Committee to be printed *in extenso.*]

On employait autrefois des barreaux longs et lourds, sans doute par l'idée que les forces agissantes étaient plus grandes et que les résultats devaient être plus sûrs. Les barreaux de Gauss pesaient quelquefois plusieurs livres. La boussole de Gambey pour la déclination avait un aimant d'environ 50 cent. de longueur ; celui de la boussole de variations était encore plus long et les aiguilles d'inclination n'avaient pas moins de 25 cent. Depuis plusieurs années on a beaucoup réduit les dimensions des barreaux ; ce qui permit de rendre les instruments plus faciles à transporter, et je crois qu'au point de vue de la sensibilité on n'a fait qu'y gagner, comme pour le compas de Lord Kelvin.

Considérons, en effet, un barreau de forme déterminée (tige à section rectangulaire, par exemple). Soient

m la masse du barreau.
p son poids.
ρ le rayon de giration autour d'un arc transversal passant par le milieu.
$k = m\rho^2$ le moment d'inertie.
M le moment magnétique.
H la composante horizontale du champ terrestre.

Désignons par les mêmes lettres accentuées, m', p', ρ', k', M', les grandeurs correspondantes pour un aimant *de même forme* dont la longueur est f fois celle du premier. On peut admettre que l'aimantation reste la même dans les deux cas, quoique toute chose égale l'avantage restera encore pour diverses raisons aux aimants courts. On aura alors

$$\frac{M'}{M}=\frac{m'}{m}=\frac{p'}{p}=f^3.$$

$$\frac{\rho'}{\rho}=f, \qquad\qquad \frac{k'}{k}=\frac{m'\rho'^2}{m\rho^2}=f^5.$$

1° Si les deux aimants sont suspendus à des fils sans torsion sensibl pour déterminer le produit HM, les durées d'oscillations t' et t donnent rapport

$$\frac{t'^2}{t^2}=\frac{k'}{HM'}\cdot\frac{HM}{k}=\frac{k'}{k}\cdot\frac{M}{M'}=f^2.$$

$$(1) \qquad\qquad \frac{t'}{t}=f.$$

2° La torsion des fils de suspension n'est jamais nulle. Dans un fil unique la section s doit être proportionnelle au poids du barreau (abstraction faite de l'étrier) ; par suite

$$\frac{s'}{s}=\frac{p'}{p}=f^3.$$

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[1] Question referred to the Permanent Committee by the Paris Meteorological Conference.

D'autre part le couple de torsion c'est proportionnel au carré de la section

$$\frac{c'}{c}=\frac{s'^2}{s^2}=f^6.$$

Le rapport du couple de torsion au couple directeur magnétique est donc

$$(2) \qquad \frac{c'}{\text{HM}'}=\frac{c}{\text{HM}}\cdot\frac{f^6}{f^3}=\frac{c}{\text{HM}}f^3.$$

3° S'il existe un frottement dans l'appareil, comme pour les aiguilles montées sur pointe ou les aiguilles d'inclinaison dont les tourillons roulent sur des plans, le frottement est proportionnel au poids du barreau. Le couple directeur magnétique est lui-même proportionnel au moment magnétique et, par suite, au poids. Tous les barreaux de même forme sont donc équivalents à ce point de vue. Sans aller plus loin, examinons les conséquences des équations (1) et (2). Il y a tout avantage à rendre les oscillations rapides. Si on veut les mesurer, l'opération est plus facile, sans avoir recours aux méthodes compliquées de Gauss. D'autre part, les oscillations ramortissent beaucoup plus vite et l'on n'a pas à craindre les variations de toute nature, telle que les déplacements du zéro, pendant la série des observations.

La remarque s'applique encore mieux aux instruments de variations qui prennent sans retard et sans osciller la position qui convient à l'état actuel.

Donc supériorité des aimants courts.

L'équation (2) montre aussi que le rapport du couple de torsion du fil au couple directeur magnétique est proportionnel au cube f^3 du rapport de symétrie et par conséquent du poids du barreau. Toutes les causes d'erreur qui entraîne la suspension sont donc exagérées pour les barreaux lourds.

On verrait de même que les dimensions des barreaux ne jouent pas de rôle dans les expériences de déviation pour déterminer la valeur absolue de H, puisque les formules ne dépendent que du rapport des longueurs du barreau déviant et du barreau dévié.

Enfin les causes d'erreur étrangère, telle que la présence de petits traces de fer dans l'instrument ou dans le voisinage, deviennent importants et impossibles à éliminer lorsque le moment magnétique et la distance des pôles deviennent trop grands.

A tous les points de vue il y a donc intérêt à réduire autant que possible les dimensions des barreaux, si la précision des lectures d'angles reste suffisante.

After considering this report the Permanent Committee passed the following resolution:—'Unless special reasons exist to the contrary, it is desirable that the dimensions of the magnets should be as small as possible, provided that the accuracy of the results is adequately maintained.'

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2. *On the Construction of Magnets of Constant Intensity under Changes of Temperature.* *By* J. R. Ashworth, *B.Sc.*

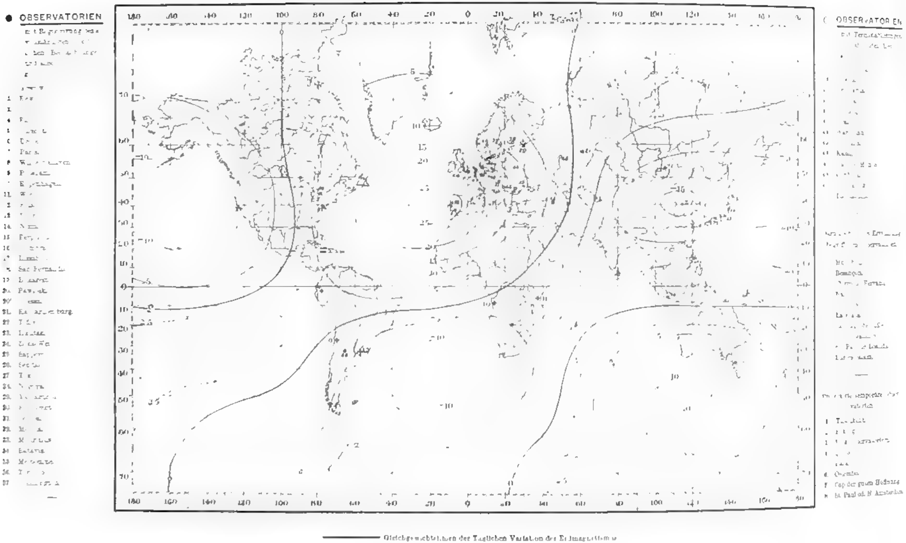
The paper describes experiments on a remarkable property of drawn steel wires. Magnets made of such wires, after a series of heatings and coolings, reach a cyclic state in which, contrary to general experience, an *increase* of temperature

ÜBERSICHT

ÜBER DIE

ZUR ZEIT BESTEHENDEN MAGNETISCHEN OBSERVATORIEN

ZUSAMMENGESTELLT VON M. ESCHENHAGEN IN POTSDAM



Illustrating Paper by Professor von Bezold and General Rykatcheff on the Establishment of Temporary Magnetic Observatories in Certain Localities, especially in Tropical Countries.

produces an *increase* of magnetic moment, and *decrease* of temperature a *decrease* of magnetic moment. It is easy, by several processes which are described, to change this abnormal effect to the normal one, in which *higher* and *lower* temperatures produce *lower* and *higher* magnetic moments respectively. In passing from the abnormal to the normal state by any of these processes a stage is reached at which change of temperature neither increases nor decreases the magnetic moment, and, for changes within the atmospheric range of temperature, the intensity of such a magnet remains constant.

An account is given of the behaviour at different times of magnets of constant intensity which have been tested at intervals during eighteen months. In conclusion, experiments on the cause of the abnormal thermo-magnetic effects are described.

FRIDAY, SEPTEMBER 9.

The following Papers were read :—

1. *On the Establishment of Temporary Magnetic Observatories in Certain Localities, especially in Tropical Countries. By* Professor VON BEZOLD and General RYKATCHEFF.

[Ordered by the General Committee to be printed *in extenso.*]

[PLATE V.]

Die nachstehenden Vorschläge stützen sich wesentlich auf eine Abhandlung, welche der eine der Unterzeichneten im Jahre 1897 veröffentlicht hat.[1] In dieser Arbeit wurde versucht, durch Vergleichung mit den Beobachtungen die Hypothese zu prüfen, dass die Kräfte, welche die erdmagnetischen Erscheinungen hervorrufen, in der Erdoberfläche selbst ein Potential besitzen ; auf Grund von Werthen, die ihm Herr A. Schmidt für je 72 um je 5 Längengrade von einander abstehende Punkte auf 4 Parallelkreisen mitgetheilt hatte, gelang der Verfasser zum Schluss, dass die in Procenten der Amplitude des Potentials ausgedrückten Abweichungen von jener Hypothese um den 40-45 Grad nördlicher Breite am grössten ausfallen, d. h. also gerade in jenen Breiten, für welche die meisten und besten Beobachtungen vorliegen ; diese Abweichungen erreichen hier Werth bis zu 8% der Amplitude, während sie in niedrigen Breiten nur wenige Beobachtungen vorhanden sind, viel kleiner sind theilweise sogar ganz verschwinden. Für die Theorie des Erdmagnetismus wäre es von höchster Wichtigkeit, darüber Gewissheit zu erlangen, ob dieses Resultat nicht vielleicht durch den Mangel an Beobachtungen, besonders aus dem Aequatorialgebiete, bedingt ist.

In derselben Arbeit hat der Autor auf Grund der von A. Schuster[2] mitgetheilten Werthe eine Karte entworfen, welche für den Sommer ein anschauliches Bild vom Verlaufe der Gleichgewichtslinien des Potentials der täglichen Variation giebt ; die Darstellung der Karte bezieht sich auf den Mittag nach Greenwicher Zeit.

Unter Annahme der Hypothese, dass die tägliche Variation ausschliesslich und unmittelbar durch ein unveränderliches System von Kräften

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[1] *Sitzungsberichte der K. Preuss. Akad. d. Wissensch. zu Berlin*, xviii. 1, April 1897.

[2] *Philos. Transactions of the Royal Society of London*, vol. 180A.

hervorgerufen wird, welche die Erde umkreisen, würden alle auf demselben Parallelkreise belegenen Punkte auch die gleiche Tagesschwankung der Süd-Nord- und West-Ost-Componente des Erdmagnetismus besitzen. Dieses theoretisch abgeleitete Resultat wird durch die Beobachtungen zum Theil bestätigt; doch liegen leider zu wenig Beobachtungen vor, um diese Frage endgiltig entscheiden zu können. Ein Blick auf die Karte, von welcher eine Copie beiliegt, zeigt uns, welch' eine hervorragende Rolle bei diesem Curvensystem die Parallelkreise 38 Grad nördlicher Breite und 40 südlicher Breite spielen, über welche die Aktionscentren für die tägliche Periode hinwegzuziehen scheinen, so dass es vom grössten Werthe wäre, sowohl aus den diesen Parallelkreisen benachbarten Breiten, als auch aus den zwischen beiden liegenden, d. h. aus den Tropengegenden genügende Beobachtungen zu besitzen.

Schliesslich wird in der citirten Arbeit auf die hohe Bedeutung hingewiesen, welche detaillirte bis auf die Secunde genau gleichzeitige Simultanbeobachtungen haben, die zu vereinbarten festen Terminen, wenn auch nur im Laufe eines kurzen Zeitabschnitts, anzustellen wären. Derartige Beobachtungen, wie sie auf Anregung von Herrn Professor Eschenhagen[1] im Jahre 1896 versuchsweise ausgeführt wurden, können gleichfalls nur in magnetischen Observatorien gemacht werden, welche über die ganze Erde vertheilt sein müssen.

Aus diesen Gründen wäre die Existenz einer Reihe von Observatorien und insbesondere unter den bezeichneten Breitengraden besonders wünschenswerth. Wenn wir aber die Vertheilung der bestehenden Observatorien ins Auge fassen, die auf der Karte durch schwarze Punkte bezeichnet sind, so sehen wir, dass bloss in Europa ein hinreichend dichtes Netz von Observatorien vorhanden ist; in allen übrigen Erdtheilen treffen wir eine deprimirende Oede an. In Bezug auf die erwähnten besonders interessanten Breitengrade genügt die Bemerkung, dass im ganzen Aequatorialgürtel zwischen 10° nördlicher und 10° südlicher Breite nur ein einziges Observatorium, dasjenige in Batavia, besteht, und dass ferner auf der südlichen Halbkugel südlich vom 35 Breitengrade gleichfalls nur ein Observatorium (in Melbourne) functionirt; auf der nördlichen Halbkugel existirt östlich von Tiflis, zwischen dem 35 und 45 Breitengrade, auf einer Strecke von 100 Längengraden kein einziges Observatorium, und ebenso ist weiter östlich von Japan auf eine Entfernung von 140 Längengraden auch kein Observatorium vorhanden.

Für die Untersuchung der erdmagnetischen Erscheinungen auf der ganzen Erde, für die Entwickelung der Theorie dieser Erscheinungen und für die Prüfung der bisher aufgestellten Hypothesen ist es daher unumgänglich nothwendig, dass die bezeichneten gegenwärtig bestehenden grossen Lücken wenigstens für's erste darauf beschränken, eine gewisse Minimalzahl, sei es auch nur temporärer Observatorien, zu begründen. Die Errichtung eines Observatoriums in Taschkent, die Wiederaufnahme der abgebrochenen Beobachtungen im früheren russischen Observatorium zu Peking (resp. die Begründung eines neuen magnetischen Observatoriums in Wladiwostok), sowie die Organisation von magnetischen Beobachtungen beim Lick-Observatorium würden die Lücken in der Reihe der magnetischen Observatorien um den 40 Grad nördlicher Breite ergänzen; im Aequatorialgürtel könnte die Begründung von Observatorien in Quito, Pará, Colombo, sowie die Eröffnung der in St. Paul de Loanda und

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[1] *Terrestrial Magnetism*, vol. i. p. 55.

Dar-es-Salam bereits projectirten Observatorien den gegenwärtigen ungenügenden Zustand verbessern. Auf der südlichen Halbkugel müssten ausser den bereits projectirten Observatorien in Santiago de Chile und La Plata noch ein Observatorium am Cap der guten Hoffnung und ein anderes wo möglich auf einer der Inseln St. Paul oder N. Amsterdam begründet werden. Die Subkommission empfiehlt somit, ausser den bereits früher projectirten, beständigen Observatorien, sich für die Begründung folgender temporärer Observatorien zu verwenden :

1. Taschkent	Russland.
2. Peking	China.
3. Lick-Observatorium	Vereinigte Staaten N. A.
4. Quito	Ecuador.
5. Pará	Brasilien.
6. Colombo	Anglo-Indien.
7. Cap der guten Hoffnung	England.
8. St. Paul oder N. Amsterdam	Eine der grossen Seemächte, z. B. Frankreich.

Den hier aufgezählten sollte sich wenigstens noch ein Observatorium in höheren südlichen Breiten anschliessen, sei es auf den Falklandsinseln, auf Kap Horn oder an einem anderen in diesen Breiten gelegenen Punkte.

Im Hinblick auf die Schwierigkeiten, welche die Errichtung gerade dieses Observatoriums bieten wird, schien es jedoch richtiger, keinen bestimmten Vorschlag zu machen, sondern zunächst nur eine allgemeine Anregung zu geben.

After considering this report the Permanent Committee passed the following resolution:—'That it is desirable that temporary magnetic observatories should be established in places such as the following:—Taschkent, Peking, the Lick Observatory, Quito, Pará, Colombo, Cape of Good Hope, St. Paul or N. Amsterdam, Honolulu, and Point Barrow or Sitka, or some other station in a high latitude in North America.

'That these observatories should, if possible, be provided with both absolute and variation instruments, of which the latter should be self-registering instruments, and should be established for at least seven, and, if possible, for eleven or twelve years, *i.e.*, for a complete sunspot period.'

2. *The Application of Terrestrial Magnetism to the Solution of some Problems of Cosmical Physics.* *By* ARTHUR SCHUSTER, *F.R.S.*

In dealing with a subject in which a great part of the work is purely statistical, it is always advisable to keep in mind the real problems which form the ultimate object of the statistical inquiry. It may be of interest, therefore, to the Congress to have a short summary of what I consider to be the most pressing questions of cosmical physics on which the science of terrestrial magnetism may throw some light.

We know that the greater part of the magnetic forces which we observe on the surface of the earth are due to inside causes, but our information is barely sufficient at present to decide whether an appreciable portion, possibly amounting to 5 per cent. of the whole, may not have an outside origin. The outside forces must be divided into two different types, according as they are stationary in space or revolve with the earth. Stationary outside forces may be due to magnetic effects of the sun or moon, or generally to magnetic induction in that part of space through which the earth moves. A magnetism fixed in space would give rise to a variation having the sidereal day for period, and if the force is of solar origin there would also be an annual period. If the sun were transversely magnetised we should, in addition, have two periodicities, neither of which, as I have lately shown, is, as commonly supposed, equal to the synodical revolution of the sun, but one of which is equal to the period of sidereal revolution, and the other as much larger than the synodical revolution as that is larger than the sidereal period.

In a Presidential Address to the Royal Society ('Proc. Roy. Soc.,' vol. lii. p. 305), Lord Kelvin made an appeal for the investigation of those periodicities which might be due to solar magnetism. But, on entering into the question, I find that it would be necessary to compare carefully the daily variations in the southern and northern hemispheres. At present we know too little of the movements of the magnetic needle in the southern hemisphere to attack the problem with success. I should consider it, therefore, a matter of the greatest importance to obtain comparisons in the daily curves on stations of approximately the same latitude north and south of the equator. A few temporary observations at well-chosen places would be sufficient for this purpose.

My investigations on the diurnal variation have led me to the conclusion that part of the effect is due to currents induced inside the earth, and the results seemed to satisfy the conclusion that the interior of our globe was a better conductor than the outer layers. But daily variations have also been observed in the earth currents which pass close under the surface of the earth, and it is doubtful at present how much of the observed daily variation is due to these earth currents. As the latter must be affected considerably by the nature of the ground, as regards its electric conductivity, it seems to me to be of interest to make observations at places not too far apart from each other on the same circle of latitude, and to compare especially the daily variations on small islands surrounded by sea with those on land stations. There, again, a short series of observations will be sufficient. The possibility of obtaining by means of the diurnal period information as to the electric conductivity of the interior of the earth seems to me to justify a closer investigation than the present data allow us to enter into.

That component of a possible solar magnetisation which is parallel to the earth's axis will produce a permanent effect, adding itself to the normal elements of terrestrial magnetism. Similarly, any magnetic forces which revolve with the earth, either because they have their origin in electric currents in the atmosphere, or because they are induced in space by the revolution of the earth, will produce permanent effects which can only be separated from the intraterrestrial causes by the analysis of spherical harmonics. Hence attention should be given to the gradual perfection of the calculations which, originated by Gauss, have recently been developed by Ad. Schmidt.

But the first step towards the improvement in the analysis by spherical harmonics must be the definite answer to the question as to whether the whole, or nearly the whole, of the observed forces have a potential. As far as is shown by direct observations in limited regions on land, the line integral of magnetic force taken round a closed line vanishes. On the other hand, if the available observations over the whole of the globe are collected, Ad. Schmidt has shown that a quite appreciable portion does not fit in with a potential. It might be thought that electric currents traverse the earth's surface chiefly over the ocean districts or in the polar regions; but it seems almost impossible to reconcile the values obtained by Schmidt for these currents with the known facts of atmospheric electricity. On the whole, it seems most probable that our measurements of magnetic forces over some of the ocean regions are affected by a systematic error.

It seems to me that the whole science of terrestrial magnetism is almost at a standstill until this point has been cleared up.

I believe that the greatest service that could be rendered to the science of terrestrial magnetism would be a magnetic survey over some line, passing as nearly as may be found possible along a circle of latitude round the earth. Two lines, one in the northern and one in the southern hemisphere, would be better than one; but even leaving the southern hemisphere out of account, the question raised by Ad. Schmidt should be settled as soon as possible by a direct determination of the integral line of magnetic force round the earth.

It is worth pointing out that a ship may do useful service to our subject without making a single magnetic observation. If a vessel was to start from Europe with orders to sail always at right angles to the direction of the magnetic needles, it would trace out an equipotential line and thus connect points of equal potential in the American continent and in Europe. The drift of the vessel, owing to wind and sea currents, would, of course, slightly change its course, and some corrections would be necessary, involving the approximate knowledge of the magnetic forces, which are probably known with sufficient accuracy for that purpose.

If a suitable ship were to be found willing to enter on such an expedition, the value of the results would, of course, be much increased by more accurate magnetic determination. A full discussion of the best available method for such determination seems to me to be called for, and it is probable that the beautiful marine galvanometer of Mr. Sullivan may be made useful for the purpose. Perhaps the Conference will initiate the appointment of a Committee to draw up a report on the subject.

In conclusion, I may sum up the cosmical and terrestrial problems which we may hope to bring nearer their solution by magnetic observations:—

1. The possibility of magnetic induction of that part of space through which the earth is moving, either due to solar magnetisation or to some other cause.
2. The electric conductivity of space.
3. The distribution of electric currents in the atmosphere giving rise to the diurnal variation.
4. The distribution of electric currents in the atmosphere giving rise to permanent magnetic force.
5. The electric conductivity of the interior of the earth.
6. The possibility of electric currents traversing the surface of the earth.

3. *Antrag auf Massnahmen zur systematischen Erforschung der Saecularvariationen der erdmagnetischen Elemente. Von* DR. AD. SCHMIDT *in Gotha.*

Bei dem lebhaften Interesse, das man in den letzten Jahren wieder begonnen hat der erdmagnetischen Forschung zuzuwenden, ist zu hoffen, dass die grossen Lücken unsrer Kenntniss von der räumlichen Verteilung der magnetischen Kraft in nicht zu ferner Zeit wenigstens einigermassen ausgefüllt sein werden. Soll es indessen möglich sein, die zu erwartenden Messungen in vollem Masse auszunützen, so muss vor allen Dingen für eine hinreichende Feststellung der saecularen Aenderungen gesorgt werden, ohne die (von ihrem selbständigen Werte ganz abgesehen) die Reduction der natürlich über viele Jahre zerstreuten Beobachtungen auf eine bestimmte Epoche unmöglich ist.

Die Bestimmung der saecularen Variationen hat auch schon bisher stets die grösste Schwierigkeit und die Hauptquelle der Unsicherheit bei allen Darstellungen der erdmagnetischen Kraftverteilung gebildet, und dies wird, wenn nicht genügende Vorkehrungen zur Beseitigung des bestehenden Uebelstandes getroffen werden, in Zukunft immer mehr der Fall sein. Gegenüber den gesteigerten Anforderungen an Genauigkeit, die wir heute stellen müssen und bei den verfeinerten jetzigen Messungen auch stellen können, genügt es nicht mehr, eine oft sehr ungleichartige Reihe von Messungen, die zufällig im Laufe der Jahre ungefähr an demselben Orte gemacht worden sind, zusammenzufassen und daraus—nicht selten durch Extrapolation—Werte der saecularen Schwankung abzuleiten. Und es macht sich immer empfindlicher merklich, wenn auf weiten Gebieten nicht einmal solche unvollkommene Messungsreihen vorhanden sind.

Nach der jetzigen Lage der Wissenschaft müssen wir es als durchaus notwendig erachten, dass an einer nicht zu kleinen Zahl von Orten, die möglichst gleichmässig über die Erde zerstreut sind, regelmässig wiederholte Beobachtungen aller erdmagnetischen Elemente mit verglichenen Instrumenten und zwar stets genau an demselben Punkte angestellt werden, um den Einfluss von lokalen Störungen auszuschliessen.

Magnetische Observatorien sind dazu natürlich keineswegs nötig; sie würden andrerseits, auch wenn ihre Zahl noch beträchtlich vermehrt werden sollte, nicht ausreichen. Für den bezeichneten Zweck genügen, wenigstens bis auf weiteres, viel einfachere Vorkehrungen, die bereits einen grossen Fortschritt gegenüber dem jetzigen Zustande darstellen würden. Wenn etwa an jenen Punkten, die man Saecularstationen nennen könnte, von Zeit zu Zeit—etwa alle 5 Jahre—Messungen angestellt würden, so dürfte dies zunächst durchaus genügen. Es scheint mir eine der wichtigsten und dringendsten Aufgaben zu sein, Massnahmen zu beraten, die dazu dienen können, dieses Ziel zu erreichen, ohne aussergewöhnliche Mittel, besonders in pecuniärer Beziehung, zu erfordern. Auf eine solche Massnahme möchte ich besonders hinweisen, nämlich auf die wünschenswerte Beteiligung der im Ausland stationierten Schiffe der Kriegsmarinen der seefahrenden Nationen—eine Beteiligung, die man bei dem grossen praktischen Interesse, das gerade eine zuverlässige Bestimmung der Saecularvariation für die Vorausbestimmung der erdmagnetischen Elemente besitzt, wohl schwerlich vergebens erbitten würde. Schon jetzt werden ja vielfach die Reisen dieser Schiffe u. a. gelegentlich zur Anstellung magnetischer Beobachtungen verwertet; was hier gewünscht wird, ist weniger eine starke Vermehrung solcher Messungen, als vielmehr eine planmässigere und nach internationalem Abkommen geregelte Auswahl der Stationen und eine annähernd regelmässige Wiederholung der Messungen an genügend vielen dieser Stationen. Gerade dieser letztere Wunsch ist ohne Schwierigkeit zu erfüllen, da die Schiffe der Kriegsmarinen auf ihren Reisen im allgemeinen immer wieder dieselben Punkte berühren. Ohne dass die sonstigen Aufgaben, denen diese Schiffe zu dienen haben, beeinträchtigt würden, liessen sich daher an zahlreichen Orten—Hafenplätzen des Festlandes wie von Inseln—die gewünschten Beobachtungen leicht gewinnen, etwa in der Weise, dass in einem mehrjährigen Cyklus jeder Ort einer bestimmten Gruppe je einmal an die Reihe käme. Ein international geregeltes Zusammenwirken der Marinen der verschiedenen Staaten würde dabei den Vorteil gewähren, dass mit bestimmt begrenzten Mitteln möglichst viel erreicht werden könnte, weil durch eine planmässige Verteilung der Stationen die Arbeitsvergeudung vermieden würde, wie sie in einer zwecklosen Anhäufung von Beobachtungen an identischen oder sehr nahe benachbarten Punkten läge.

Es ist richtig, dass durch die im vorhergehenden vorgeschlagenen Beobachtungen nicht allen berechtigten Wünschen entsprochen würde, denn es würden dabei manche weitausgedehnte Gebiete keine Berücksichtigung finden, so besonders die höheren Breiten der südlichen Halbkugel. Aber es würde immerhin ein auf anderem Wege schwer zu gewinnendes, wertvolles Beobachtungsmaterial zusammengebracht und dauernd ergänzt werden. Die Untersuchung jener abgelegenen, z.T. schwer zugänglichen Gebiete müsste nach wie vor besonderen Unternehmungen vorbehalten bleiben.

Auf Grund dieser, hier nur kurz angedeuteten, aber leicht weiter auszuführenden Betrachtungen erlaube ich mir den Antrag zu stellen:

Das internationale Comitee möge—

1. Erwägungen darüber anstellen, wie die Gewinnung hinreichender Beobachtungen zur fortlaufenden Ermittelung der Saecularvariation eingeleitet und dauernd gesichert werden kann;
2. Insbesondere die hydrographischen Aemter der Kriegsmarinen aller seefahrenden Staaten um ihre Mitwirkung dabei in der zuvor angedeuteten Weise zuersuchen.

4. *On Simultaneous Magnetic Observations.*
By Professor Dr. ESCHENHAGEN. (*Potsdam.*)

Under this head Dr. Eschenhagen gave an account of the results obtained at Potsdam by increasing the sensitiveness of the self-registering horizontal magnetic force instrument, till 1 mm. represented ·000004 C.G.S. unit and 24 cms. one hour.[1] Under these conditions, well-marked waves of period about 30 seconds,

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[1] *Sitz. Ber. Akad.*, June 24, 1897.

and amplitude about ·000012 C.G.S. unit, can at times be detected, and have been shown not to be due to any peculiarities of the instrument used. They occur generally between 6 A.M. and 6 P.M., but up to the present no direct effect of solar radiation on them has been proved. In the records taken at Potsdam and at Wilhelmshaven during 1895 they appear, within the limits of errors of observation, simultaneously; but till more extensive observations have been made it is impossible to say how far this may be general.

Dr. Eschenhagen also gave an account of his further work on the frequency of occurrence of these small waves at Potsdam during the different hours of the day and the various months of the year, and exhibited curves embodying his results.

He considered that these waves were of sufficient importance to justify the investigation of them being taken up by all observatories, and suggested that similar self-registering instruments should be used at all stations, and that both the north and west components should be recorded.

5.[1] *Discussion on Monthly Means.*

M. Moureaux described the results of determining the monthly mean declination by the various methods which have been used by magneticians. The results obtained differ considerably from each other, in two cases by 14 per cent. He considered that two means should be calculated: the first by taking all days into account, the second by taking only undisturbed days.

Messrs. Rykatcheff, Mascart, Eschenhagen, Schuster, Snellen, Rücker, and Schott took part in the discussion which ensued.

After the discussion the following resolution was passed by the Permanent Committee:—'In calculating monthly means all days are to be taken into consideration. It is desirable to give in addition means calculated without taking disturbed days into account.'

6.[1] A discussion was held as to the publication of the differences between the hourly means of the components of the magnetic force (X,Y,Z) and the monthly means.

After the discussion the following resolution was adopted by the Permanent Committee:—'It is desirable to publish the monthly means of the Geographical Components of the Magnetic Force for each month, and also the differences between the hourly means for each month and the monthly means for that month.'

7. *On Magnetic Observations in the Azores. By* ALBERT, Prince of Monaco.

After having perceived the capital importance of the Azores, from their geographical position, for the establishment of meteorological observatories with a view to weather predictions, I thought that these observatories might be of service to other branches of science. For instance, the communications of Messrs. Neumayer, Mascart, von Bezold and other eminent meteorologists, to the International Conference of Meteorologists in 1896 show that magnetic observations made at the Azores would offer the following advantages: (1) a situation near latitude 40° N. (page 22). (2) Remoteness from the permanent causes of perturbation of actual magnetic observation, such as electric lighting, tramways, and other applications of electricity; and (3) a geographical position intermediate between Europe and America, capable of furnishing most useful indications for the comparison of the magnetic curves obtained in these two parts of the world (pp. 36 and 90).

The examination of these considerations and different interviews which I had with M. Mascart, Director of the Bureau Centrale Météorologique of France

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[1] Question referred to the Permanent Committee by the Paris Meteorological Conference.

convinced me of the advantage which would be gained if Captain Chaves, Director of the Meteorological Observatory of Ponte Delgada, came to Europe to study the practical details of the magnetic service there. I therefore communicated my ideas to the Portuguese Government, who recalled Captain Chaves to undertake a mission in this sense.

Captain Chaves, after having finished his studies at the observatory of St. Maur under the enlightened direction of M. Moureaux, has pointed out to me the importance of taking the present opportunity of magnetically reconnoitring the archipelago, as a preliminary to the definitive installation of the observatory. This would be useful, not only to determine the value of the different magnetic elements, till now almost unknown,[1] but besides, to determine in the island of St. Michael, which appears likely to present conditions favourable to the installation of the central observatory of the Azores, the locality most suitable for the combined services of meteorology and magnetism.

Feeling certain that the views of Captain Chaves are just, and well knowing his competence, being also aware that the Portuguese Geodetic Commission finished last year the survey of the island of St. Michael, and that this year it will finish the survey of the neighbouring island of Santa Maria, I have resolved to undertake the charge of the above-mentioned magnetic reconnaissance.

With this end I am now having the necessary instruments constructed; and I announce to the International Commission that I hope to be able to put Captain Chaves in the position to be able to commence the magnetic reconnaissance of the Azores towards the month of April of next year.

8. *On Magnetic Observatories in Cape Colony.* *By* Dr. BEATTIE *and* Mr. MORRISON.

9. *Sur le Mouvement diurne du Pôle Nord d'un Barreau Magnétique suspendu par le centre de gravité.* *Par* J. B. CAPELLO.

[PLATES VI.–VIII.]

En combinant les variations diurnes de l'inclinaison avec celles de la déclinaison, sur un plan perpendiculaire à la direction de l'inclinaison, résulte une courbe fermée.

Les variations ou écarts de l'inclinaison sont positives vers le sud, et celles de la déclinaison positives vers l'ouest.

Il faut avertir que les écarts de la déclinaison doivent être multipliés par le cosinus de l'inclinaison, afin de les projeter sur un plan perpendiculaire à la même inclinaison.

Il est intéressant de comparer ces courbes obtenues en divers points ou stations du globe.

La 1ère Planche contient les courbes de Kew, Paris (Parc St Maur), Perpignan et Lisbonne en 1894 et 1895.

Les courbes de Kew et de Lisbonne sont déduites des jours tranquils (cinq jours choisis à chaque mois), celles de Paris et de Perpignan sont déduites de tous les jours.

La 2ème Planche contient les courbes de Lisbonne et de Kew de 1896; de St Pétersbourg (1873–85) et des jours dits normaux, et celle de Lisbonne de 1864–72, excepté les perturbations, d'après la méthode du Général Sabine.

La 3ème Planche contient les variations diurnes du Bifilaire, du vertical et de l'inclinaison à Lisbonne et Kew, 1894–95–96.

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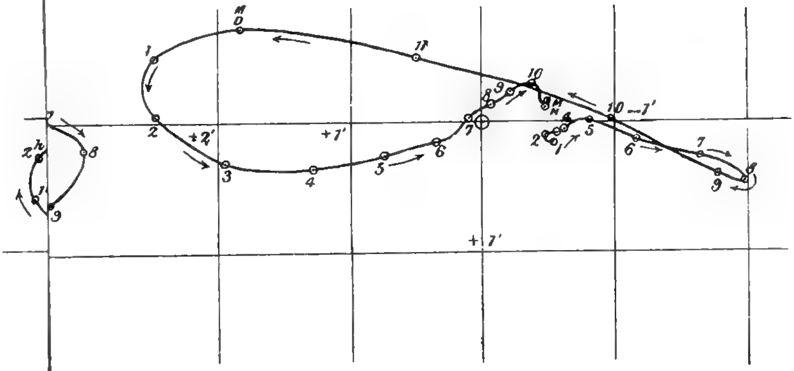
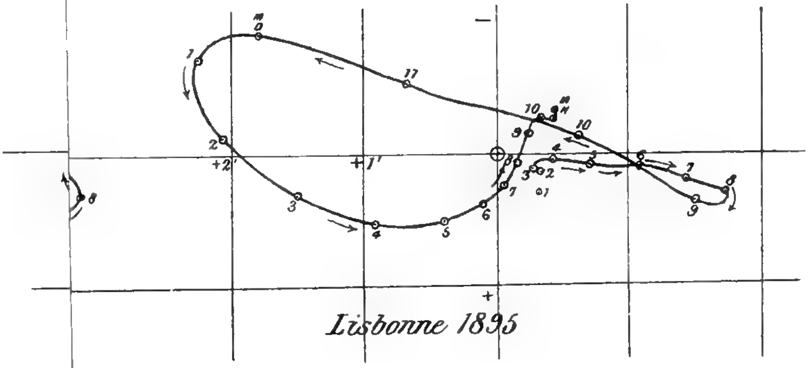
[1] In fact, even the value of the Declination, one of the most important magnetic elements, is given for one and the same place, Horta in Fayal, with differences amounting to 1° 22′ in an interval of two years. Thus Preston in 1889 gives 25° 52′ and the *Acorn* in 1891 gives 24° 30′.



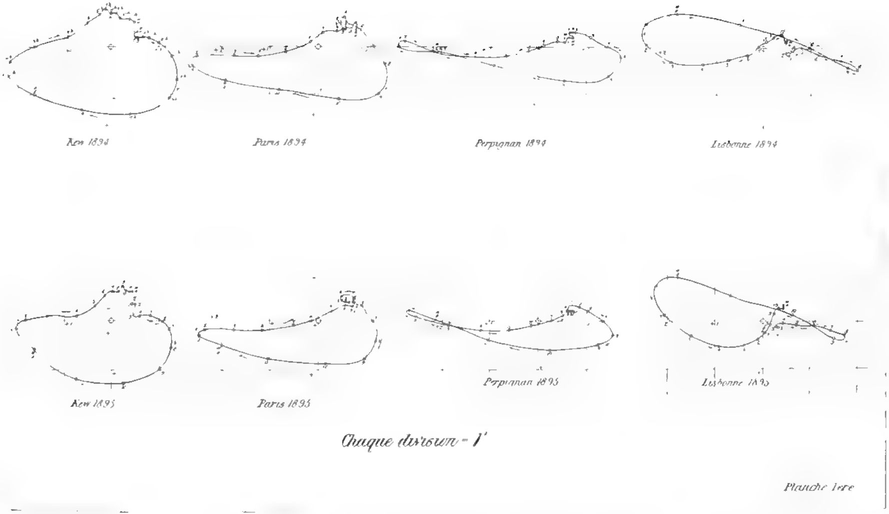
Lisbonne 1894.



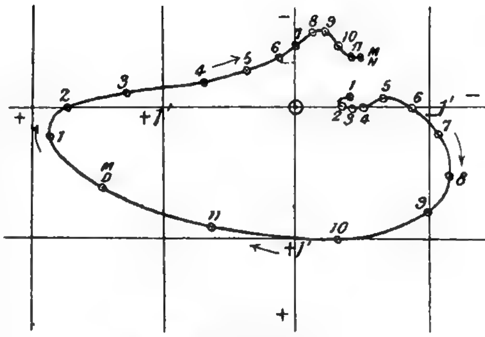
Lisbonne 1895

Planche 1ère

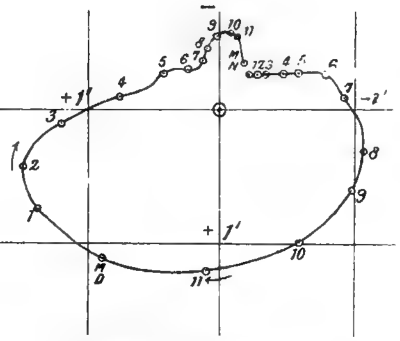
endu par le centre de gravité.'



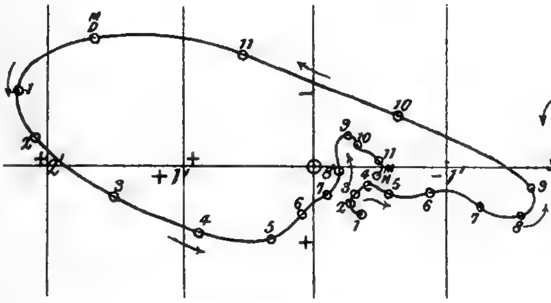
Illustrating M. Capello's Paper 'Sur le Mouvement diurne du Pôle Nord d'un Barreau Magnétique suspendu par le centre de gravité'



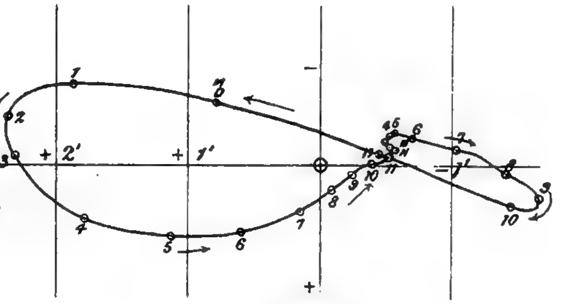
Kew 1896



St Petersburg 1873-85



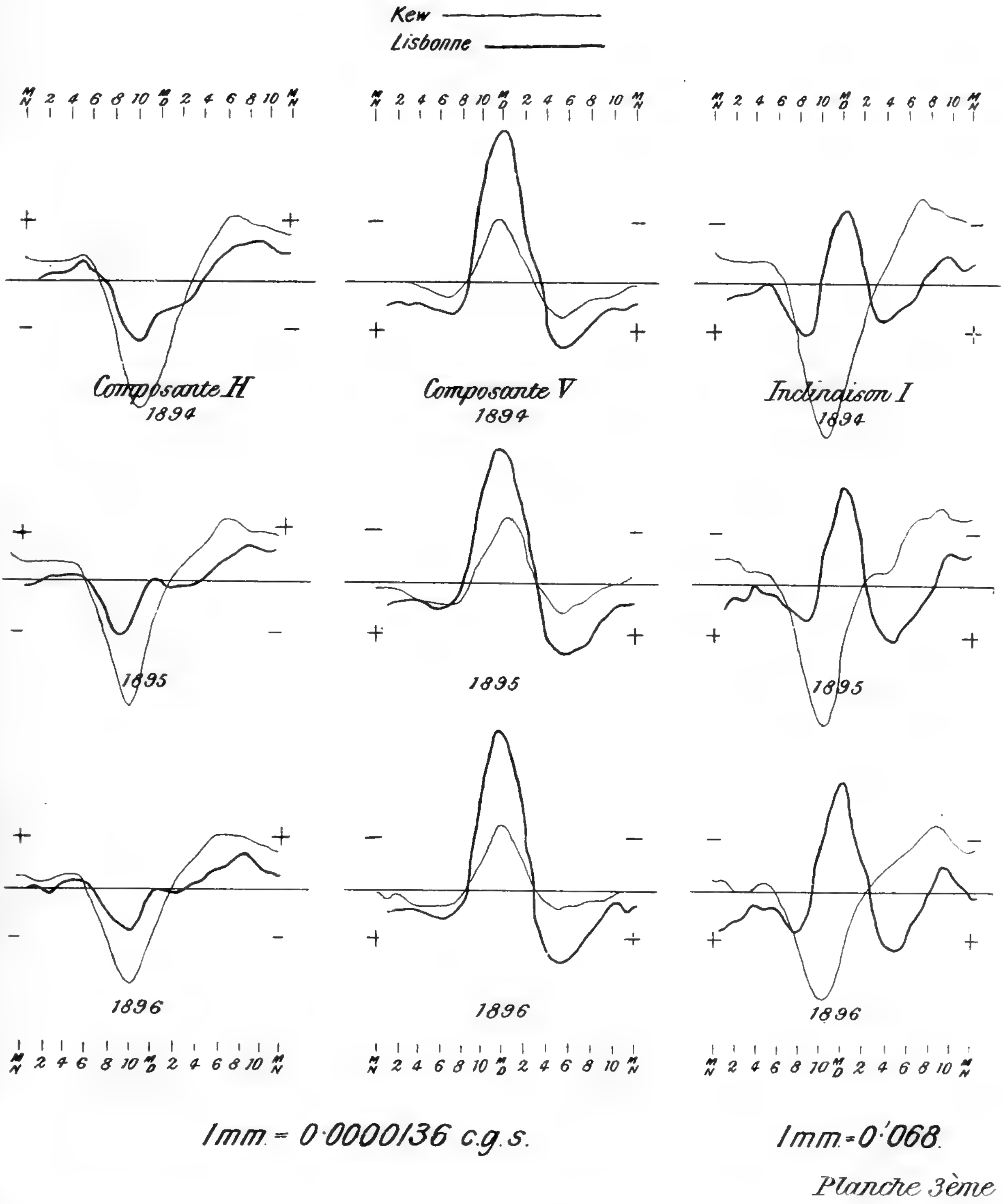
Lisbonne 1896.



Lisbonne 1864-72

Planche 2ème

Illustrating M. Capello's Paper 'Sur le Mouvement diurne du Pôle Nord d'un Barreau Magnétique suspendu par le centre de gravité.'



Illustrating M. Capello's Paper 'Sur le Mouvement diurne du Pôle Nord d'un Barreau Magnétique suspendu par le centre de gravité.'

Retournant à la $1^{\text{ère}}$ Pl. on remarque que les courbes des observatoires plus au nord sont plus rondes que celles des autres situés plus au sud.

Ainsi, Kew de 1894 et 1895 affectent la figure elliptique; ensuite vient Paris avec la forme plus allongée; Perpignan encore plus étroite et mince du coté de l'ouest, et finalement Lisbonne, dont les courbes sont plus larges du côté de l'ouest, et minces de l'est, affectant la forme d'un ∞.

On voit un autre fait plus remarquable. Tandis que dans les courbes de Kew, Paris et Perpignan le mouvement vers l'ouest, du matin au soir, est par le sud du point moyen, à Lisbonne il est par le nord, de façon que le mouvement est rétrograde en regard des autres.

Pour mieux faire ressortir cette circonstance, nous avons dans la $2^{\text{ème}}$ Pl. donné les courbes de Kew et de Lisbonne pour l'année 1896.

Le mouvement à Kew est direct (selon les aiguilles d'une montre); celui de Lisbonne est invers.

Nous avons vu ($1^{\text{ère}}$ Pl.) que la partie de la courbe du soir se déplace vers le sud, au fur et à mesure que la latitude est plus petite; on peut dire qu'à Lisbonne le déplacement est si grand qu'il traverse la courbe du matin.

Il est facile de reconnaître que les courbes plus ou moins rondes et le mouvement direct ou invers dépendent de la valeur diurne ou des écarts de l'inclinaison.

En effet, si la variation diurne de l'inclinaison est positive dans les heures du jour (9a.–2p.) le mouvement sera direct, et au contraire sera invers si elle est négative dans les mêmes heures.

Les écarts de l'inclinaison à Lisbonne sont négatifs dans les heures (10a.–2p.) au contraire de ceux de Kew, Paris, etc. Mais la variation diurne de l'inclinaison dépend des deux variations, ou des écarts des deux composantes H et V, comme il est facile de voir, d'après la formule $\delta i = \sin i \cos i \left(\frac{\delta V}{V} - \frac{\delta H}{H}\right)$.

Dans la $3^{\text{ème}}$ Pl. on voit les variations diurnes des composantes H, V, et inclinaison à Kew et Lisbonne, d'après les cinq jours calmes de chaque mois, dans les années de 1894–95–96.

On voit que les valeurs des écarts de H à Lisbonne sont plus petites que la moitié des mêmes écarts à Kew, et que, au contraire, les écarts du vertical sont plus grands que le double de ceux de Kew; quoiqu'ils aient le même signe, le résultat est de changer le signe des écarts de l'inclinaison à Lisbonne aux heures du jour (9 ou 10a.—2p.).

Afin que la forme de la courbe de Lisbonne soit semblable à celle de Kew, il faudrait, du moins, doubler les variations de H, et réduire à la moitié celles de V.

Nous avons fait l'expérience, et il a résulté effectivement une courbe très semblable à celle de Kew, avec le mouvement direct &c.

On pourrait ainsi attribuer ces différences aux valeurs de K, de H et de V, c'est-à-dire, à la mauvaise détermination de ces coefficients à Lisbonne, mais on ne doit jamais croire qu'on puisse commettre des erreurs si grossières, surtout en considérant qu'il s'agit des différentes déterminations pendant une période de 35 années.

Le but nord d'un aimant suspendu par le centre de gravité, et par un fil sans torsion, devrait décrire sur un plan perpendiculaire à leur direction une courbe égale ou très semblable à celles des $1^{\text{ère}}$ et $2^{\text{ème}}$ Pl.

Un barreau magnétique cylindrique et creux devrait être suspendu par le centre de gravité, muni de lentilles ou de miroirs, de façon que tous les mouvements seraient enregistrés sur un papier photographique placé sur un plan perpendiculaire à la direction de l'inclinaison, et ce papier devrait être disloqué rapidement à la fin de chaque heure par une certaine quantité, afin que les traces ne seraient embrouillées.

Je pense qu'un instrument semblable serait difficile à construire, surtout en conséquence de la petitesse des mouvements, mais il pourrait faire de bons services à la science du magnétisme terrestre.

SATURDAY, SEPTEMBER 10.

The Conference did not meet.

MONDAY, SEPTEMBER 12.

The following Report and Papers were read:—

1. *An Account of the late Professor John Couch Adams's Determination of the Gaussian Magnetic Constants. By* Professor W. GRYLLS ADAMS, *F.R.S.* See Reports, p. 109.

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2. *On a Simple Method of obtaining the Expression of the Magnetic Potential of the Earth in a Series of Spherical Harmonics. By* ARTHUR SCHUSTER, *F.R.S.*

The methods which have been employed so far to represent the earth's magnetic potential in a series of spherical harmonics suffer from the serious defect that the different coefficients are not determined independently of each other. Thus, in the latest and most accurate computation of Adolph Schmidt, the value of the first and largest coefficient was found to be 1,872, 1,913, or 1,921, according as the expansion is supposed to end with terms of the third, fifth, or seventh order respectively. If the value of the potential were known at all points of the earth's surface, it is well known how by a direct integration over the surface of the sphere each coefficient may be separately determined. But there are large tracts of the earth over which the magnetic forces have not been directly observed, and hence some form of interpolation is always implied in whatever method is employed. A certain amount of uncertainty results from this interpolation; but perhaps less than is commonly supposed, owing to the fact that neglecting magnetic masses actually situated in the surface, the potential, and all its different coefficients must be continuous. A complete knowledge of the potential over any finite part of the earth's surface is therefore theoretically sufficient to fix it all over the globe, and, at any rate, the continuity of the potential and of its derivatives facilitates and justifies the process of interpolation.

The whole interest of the expansion in a series of spherical harmonics centres round the first few coefficients. It would be waste of labour to obtain a complete representation of the potential, as we know that a very large number of terms would be necessary for the purpose. The sole object of the expansion can only lie in the separation of the outside and inside forces, and for the present, at any rate, our interest in the outside forces must be confined to the first few terms. Hence I consider it a matter of great importance to obtain these terms separately in such a way that their value does not depend on the number of terms which are taken into account. I believe that the following method solves the difficulty.

I write P_n for the zonal harmonic, T_n^σ for the tesseral harmonic defined by

$$T_n^\sigma = \sin^\sigma\theta \; \frac{d^\sigma P_n}{d\mu},$$

where θ is the colatitude and $\mu = \cos\theta$.

If it be required to represent a function, V, of θ and the longitude λ, in a series of spherical harmonics, it is known that the coefficients will depend on integrals of the form

$$\int V T_n^\sigma \cos\sigma\lambda \; d\omega,$$

ω being a surface element. The method I propose depends on a transformation which will allow the above integral to be expressed as a finite sum of integrals having one of the forms:

$$\int_0^{\pi}\int_0^{2\pi} \mathrm{V} \cos p\theta \cos \sigma\lambda \, d\theta d\lambda,$$

or

$$\int_0^{\pi}\int_0^{2\pi} \mathrm{V} \sin p\theta \cos \sigma\lambda \, d\theta d\lambda.$$

In other words, if V is expressed in a series the terms of which are of the form $\cos p\theta \cos \sigma\lambda$ or $\sin p\theta \cos \sigma\lambda$, and if equations are obtained once for all to give $\cos p\theta$ or $\sin p\theta$ in a series of tesseral harmonics, the problem of expansion is solved, though the independence of the higher and lower terms is not necessarily secured. The first step of the procedure which is common to all methods consists in expressing V in the form

$$\left.\begin{aligned} \mathrm{V} = \mathrm{F}_0 + \mathrm{F}_1 \cos \lambda + \mathrm{F}_2 \cos 2\lambda + \ldots \\ + \mathrm{F}_1' \sin \lambda + \mathrm{F}_2' \sin 2\lambda + \ldots \end{aligned}\right\} \quad . \quad . \quad . \quad (1)$$

where F and F′ are functions of the colatitude. If V is given discontinuously; as, *e.g.*, if it is known at the points of intersection of a number of latitude and longitude circles, each latitude circle will give an equation of the above kind. If the number of such equations is sufficient, the values of F and F′ may be plotted in terms of θ, and by calculation or mechanical integration we may obtain the values of F and F′ either as a series

$$\mathrm{F}_\sigma = a_0 + a_1 \cos \theta + a_2 \cos 2\theta + \quad . \quad . \quad . \quad . \quad (2)$$

or in the form

$$\mathrm{F}_\sigma = b_1 \sin \theta + b_2 \sin 2\theta + \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Only one of these forms is useful for our purpose, as I proceed to show.

If σ be even, T_n^σ may be expressed in the form of a finite series of the form

$$\mathrm{T}_n^\sigma = a_n \cos n\theta + a_{n-2} \cos (n-2)\theta + \ldots$$

Hence, if σ be even

$$\int_0^{\pi} \mathrm{T}_n^\sigma \cos p\theta d\theta = 0 \text{ if } p > n;$$

and the integral will also vanish if $p+n$ is an odd number. It follows that for σ even

$$\begin{aligned} \int_{-1}^{+1} \mathrm{T}_n \sin p\theta d\mu = \tfrac{1}{2}\int_0^{\theta} \mathrm{T}_n^\sigma \left[\cos (p+1)\theta - \cos (p-1)\theta\right] d\theta \\ = 0 \text{ if } p > n \text{ or if } (p+n) \text{ is an even number.} \end{aligned}$$

It follows that (σ even) we may obtain a number of series in which the sines of multiples of θ are expressed, as in the following scheme, where the numerical coefficients are left out for the sake of simplicity:—

$$\left.\begin{array}{lll} \sin \theta & = \mathrm{T}_\sigma^\sigma + \mathrm{T}_{\sigma+2}^\sigma + \ldots & \\ \sin 2\theta & = \mathrm{T}_{\sigma+1}^\sigma + \mathrm{T}_{\sigma+3}^\sigma + \ldots & \\ \vdots & & \\ \sin \sigma\theta & = \mathrm{T}_{\sigma+1}^\sigma + \mathrm{T}_{\sigma+3}^\sigma + \ldots & \\ \sin (\sigma+1)\theta & = \quad \mathrm{T}_{\sigma+2}^\sigma + \ldots & \\ \vdots & & \\ \sin p\theta & = & \mathrm{T}_{p+1} + \mathrm{T}_{p+3}^\sigma + \ldots \end{array}\right\} \quad . \quad (4)$$

Whenever p is smaller than σ the series begins with the term T_σ^σ or $\mathrm{T}_{\sigma+1}^\sigma$, according as p be odd or even; but when p is larger than σ the series begins with T_{p+1}^σ.

If, therefore, F_σ be expanded in a series of sines, as indicated in (3), the sine functions may by (4) be expressed in tesseral harmonics, and each coefficient of T_n^σ in the final representation of V will only depend on $\frac{n+2}{2}$; coefficients of the sine series if n is even, and on $\frac{n-1}{2}$ coefficients if n be odd. Thus, the first coefficient, which is of the third degree, only requires one coefficient in the series of sines, and will be independent of all the others.

For the simplest case $\sigma=0$; equations (4) resolve themselves into the well-known ones:

$$\left.\begin{aligned} \frac{4}{\pi}\sin\theta &= P_0-\frac{5}{8}P_2-\frac{9}{64}P_4-\ \dots \\ \frac{8}{\pi}\sin 2\theta &= 3P_1-\frac{7}{4}P_3-\frac{55}{128}P_5-\ \dots \\ \frac{32}{3\pi}\sin 3\theta &= 5P_2-\frac{45}{16}P_4 \\ \frac{64}{5\pi}\sin 4\theta &= 7P_3-\frac{77}{20}P_5 \end{aligned}\right\} \quad \dots\dots \quad (5)$$

Hence, to expand a function into zonal harmonics, we may, if chief attention is to be directed to the first few terms, express it in a series of the sines of multiples of θ, and substitute the above values. P_0 only occurs in the first equation, P_1 only in the second, P_2 only in the first and third, and so on.

We may show in a similar manner that if σ is odd, we must use (2) (the cosine form of the series) for F_σ.

For the expansion of

$$T^\sigma \sin\theta = \sin^{\sigma+1}\frac{d^\sigma P_n}{d\mu^\sigma}$$
$$= a_{n+1}\cos(n+1)\theta + a_{n-1}\cos(n-1)\theta + \ \dots$$

leads to the conclusion that

$$\int_{-1}^{+1} T_n^\sigma \cos p\theta d\mu = 0 \text{ when } p>n+1 \text{ and when } p+n \text{ is even.}$$

We find thus for $\sigma=1$

$$\left.\begin{aligned} \frac{8}{\pi} &= 3T_1'+\frac{7}{16}T_3'+\frac{11}{128}T_5'+\ \dots \\ \frac{4}{\pi}\cos\theta &= \frac{5}{8}T_2'+\frac{9}{64}T_4'+\ \dots \\ \frac{16}{\pi}\cos 2\theta &= -3T_1'+\frac{7}{4}T_3'+\frac{55}{128}T_5'+\ \dots \\ \frac{32}{\pi}\cos 3\theta &= -5T_2'+\frac{45}{16}T_4'+\ \dots \\ \frac{128}{27\pi}\cos 4\theta &= -7T_3'+\frac{77}{20}T_5'+\ \dots \end{aligned}\right\} \quad \dots\dots \quad (6)$$

where T_1' will only occur in the first and third equations; and generally a term of degree n will occur in $\frac{n}{2}$ equations if n be even, and in $\frac{n+3}{2}$ equations if n be odd.

In the case of the magnetic potential the quantities which are directly observed are the forces which are connected with the potential V by the relations

$$X=\frac{dV}{d\theta} \qquad Y\sin\theta=\frac{dV}{d\lambda} \quad \dots\dots \quad (7)$$

the radius of the sphere being, for simplicity's sake, taken as unity.

[X = force to north; Y = force to west; λ = longitude measured eastward.]

If $Y \sin \theta$ be expanded in a series of surface harmonics the potential V will be obtained immediately in a similar series; but somewhat difficult complications arise when V is to be obtained from the series for X. This difficulty completely disappears in the method here proposed, for X being expressed in a series of circular function, we may integrate with respect to θ without changing the nature of the series. The process to be employed may be summed up as follows:—

Express both X and Y in the form—

$$\begin{aligned} X = X_0 + X_1 \cos \lambda + X_2 \cos 2\lambda + \;. \;. \;. \\ + X_1' \sin \lambda + X_2' \sin 2\lambda + \;. \;. \;. \\ Y = Y_1 \cos \lambda + Y_2 \cos 2\lambda + \;. \;. \;. \\ + Y_1' \sin \lambda + Y_2' \sin 2\lambda + \;. \;. \;. \end{aligned}$$

and further express X_σ and Y_σ in Fourier's *cosine* series for even and in the *sine* series for σ odd. If V is then calculated by either of the equations (7) and the substitutions, or (5) or (6) of the corresponding equations are performed, the potential will be expressed in a series of spherical harmonics. The values of X and Y are not known in the polar region, but must be obtained by interpolation. The term *inter*polation is the appropriate one because the value of X_σ and Y_σ are known at the poles, vanishing there except for Y_1. Also the first σ differential coefficients of X_σ and the first $\sigma - 1$ differential coefficients of Y_σ will vanish at the same points. The value of Y_1 and Y_1' is very approximately known at the poles from previous investigations, and also its first differential coefficients will vanish.

I have not taken account of the possibility of earth currents traversing the surface of the earth in sufficient intensity to affect magnetic forces. The investigations of Adolph Schmidt have shown how the problem must be treated when their influence has to be taken into consideration. The general method of expansion here suggested will remain the same.

3. *On Magnetic Observations at Funafuti. By* Captain E. W. Creak, *R.N.*, *F.R.S.*

4. *On the Relations between the Variations in the Earth Currents, the Electric Currents from the Atmosphere, and the Magnetic Perturbations. By* Selim Lemström.

The paper contains an historical sketch of the observations and researches made on the earth currents by Lamont, Airy, Wild, Blavier, and others. The author describes the method employed by him for measuring the electromotive force of the electric currents coming from the atmosphere, and gives the evidence of the fact that the variations of earth currents occur a short time (five minutes) before the magnetic perturbations, and that the former are more numerous than the latter. From the observations in Sodankyla it is, however, proved that all magnetic perturbations are not preceded by variations in the earth currents, but that these probably are caused by electrical currents from the atmosphere to the earth, or *vice versâ*.

The proofs of that conclusion are: (1) That the magnetic perturbations in polar regions have a contrary direction to those in more southern countries; (2) That at the times of auroras the electrical current from the atmosphere varies much, and must exert on magnetic instruments a marked influence depending on their position, relative to the space within which this current is moving. It follows from this that we cannot find the causes of the magnetic variations, or, rather, perturbations, before we have investigated the earth currents and the electrical currents in the atmosphere.

The author's experience shows that we must seek the key to these relations in the polar regions. Researches have shown that the magnitude of these variations of the earth currents increases with the latitude in a very high ratio. When the diurnal variation in Pawlowsk has a value of O, 0008 volt, it rises in Sodankyla (7° more to the north) to O, 0600, or 75 times more. Moreover, we find from the lately published third volume of the observations from the international polar stations at Sodankyla and Kuttala that the earth currents as well as the electric currents in the atmosphere depend intimately on the belt of the maximum polar light. It will be very clearly seen that we also have a maximum belt of the earth currents and even of the currents in the atmosphere. The paper finishes with a proposition that the International Conference on Terrestrial Magnetism and Atmospheric Electricity should discuss the two following questions: What signification must be attributed to the earth currents and the electric current from the atmosphere in the explanation of the causes of magnetic perturbations? What is to be done for the further investigation of the connection between the magnetic perturbations and the electric currents?

The author also proposes that the International Conference should take steps for establishing two international polar stations, one in the North of America, the other in the North of Europe, both situated in the southern border of the polar light maximum belt. In connection with both these principal stations there should be a northern by-station, in which, as well as in the principal stations, all the magnetic variations, the earth currents, and the electric currents from the atmosphere, besides all meteorological observations, should be made simultaneously, and with self-registering apparatus of the best construction, the details of which ought to be stated by the International Conference.

In connection with these observations it ought to be expressed as desirable that all magnetic observatories should, if possible, establish similar observations with as identical instruments as possible. Since the researches of the electric currents from the atmosphere require points elevated about 400 m., it seems difficult to unite these observations with those in an observatory. We, however, must remember that the electrical resistance in the circuit, from the earth to the atmosphere, is so great that one can put in several miles of wire without any sensible augmentation of it. It is well understood that the mountain on which an apparatus for out- or in-streaming of electricity is placed can without serious damage be far away from the observatory.

5. *On the Interpretation of Earth-current Observations.*

By ARTHUR SCHUSTER, *F.R.S.*

If two metallic plates are inserted into the ground and connected by a wire an electric current is found to traverse the conductor, and this is generally called the 'earth current.' It is not, however, obvious at first sight what the connection is between this observed current and that which traverses the ground when the earth plates are removed. The statement sometimes made, that the observation gives the difference of potential of the earth at the two points at which the plates are inserted, would be true, provided the connecting wire has a sufficiently large resistance, if earth currents were only due to chemical or thermo-electric forces. But as there can be little doubt that earth currents are chiefly, if not entirely, effects of induction, a separate investigation is necessary as to the interpretation to be attached to the galvanometer indications.

Let A and B be two points in a line of flow of the currents traversing the earth, and consider a tube of flow passing from A to B. The specific resistance of the ground being ρ, let ρ be changed to ρ' for the material enclosed by the tube. I determine in the first place the effect of this change of resistance on the distribution of currents. The change of resistance could be counterbalanced by an electric force $-(\rho-\rho')\,u$ acting throughout the tube, where u is the density of the undisturbed currents, and it is therefore equivalent to the introduction of an electromotive force $\int(\rho-\rho')\,u\,dl$ in the tube of flow, dl being an element of its length and the integration being extended from A to B. If ρ and u are constant within the tube, the additional current flowing through it, owing to the change of resistance, will be

$$\frac{(\rho-\rho')\,ul}{R+S},$$

where R denotes the resistance of the tube, and S the resistance of the ground between A and B. If the resistivity ρ' is of the order of magnitude of that of copper, it will be small compared to ρ, and may be neglected in the above expression.

Imagine now this tube of flow between A and B to consist of two overlapping tubes, one of material equal to that of the rest of the ground, the other of copper, and let the latter tube be lifted out of the ground without altering its total resistance, but keeping its connection at A and B. The current traversing the lifted-up part will remain the same as before, provided that the electromotive forces of induction are not sufficient to produce an appreciable current in a circuit made up of the original and displaced position of the tube, a condition which will be satisfied in the case of earth currents, except perhaps at times of great magnetic storms.

We have now an arrangement equivalent to that used in earth-current observations, for the only effect of the earth plates at A and B will be to diminish the earth resistance S.

The observed current i will be connected with u by the relation

$$i=\frac{\rho ul}{R+S}.$$

The resistance R + S is measured by the introduction of an electromotive force e in the circuit; if the observed current, under these circumstances, be increased by a quantity i', the equation

$$u=\frac{ei}{\rho li'}$$

will give the current density of the earth current. It is seen that u is proportional to the conductivity of the material of which the ground is made up, and that a knowledge of that conductivity, which may vary from day to day, according to the amount of moisture contained in it, is therefore essential to a correct interpretation of earth-current observations.

If the circuit is a long one, S may be small compared to R, and the latter quantity will be $\frac{\rho' l}{a}$, a being the cross section of the wire, so that

$$u=\frac{i}{a}\cdot\frac{\rho'}{\rho},$$

which shows that the current densities in the wire and ground are in the proportion of their conductivities.

The above investigation points to the importance of measuring the conductivity of the ground wherever earth-current observations are made. Samples of the soil taken from different depths would probably give different results, and would then indicate how the current density varies with depth.

6. *On the Construction of Magnetic Observatories.* *By* Dr. SNELLEN.

A magnetic observatory should fulfil the following purposes. As it is desirable that regular observations be made in many places of the absolute values of the magnetic elements, a base-station is required for the reduction of observations. Also it is desirable to observe continuously regular variations of these elements. And, finally, there ought to be facilities for carrying on researches connected with magnetism in general.

A combination of two observatories, one for absolute measurements and another for observing and recording continually the variations of the earth's magnetism, will fulfil these conditions. It is desirable to have them in separate buildings.

Both should be constructed of non-magnetic substances; this is a necessity both for metallic connecting pieces and for the stone or other material of which the building is constructed.

Another condition is that temperature variations should be reduced as much as possible, especially in the variation observatory.

All materials employed for the construction of the magnetic observatories at De Bilt, near Utrecht, in the Netherlands, have been subjected to a most rigorous examination as to their magnetic condition before they were accepted for the buildings.

The observatory for absolute measurements consists of two rooms, one built of stone and wood, the walls being double, and the interstices filled with sawdust. It contains six pillars for making absolute measurements, at a distance from each other of four metres, to enable comparisons of instruments and methods to be made. It has no windows except in the ceiling, one above each of the pillars. The other room, of smaller dimensions, has large windows on three sides for making astronomical observations.

The observatory for variation observations consists of two rooms, wholly separated from each other and surrounded by a corridor. The whole is enclosed in a building which has double walls, 1·60 metre thick, the interstices of which are filled with loose dry peat moss, &c. Daylight is not admitted into this observatory. Diurnal temperature variations are by these means wholly excluded.

TUESDAY, SEPTEMBER 13.

A joint meeting with Sections A and G was held for the purpose of discussing the Magnetic and Electrolytic Effects of Electric Railways, at which the following Papers were read :—

1. *On the Disturbance of Magnetic Observatories by Electric Railways.*[1] *By* W. VON BEZOLD, *Director of the Potsdam Observatory.*

The demand of the authorities of the Potsdam Observatory that no electric railway with an earth return should be allowed to approach them within 15 kilometres having been characterised as exorbitant, the author states in this paper some of the reasons which have led to its being made. It was felt that a distance sufficiently great to prevent any possibility of disturbance should be temporarily fixed till experiments had been made to find to what distance from such railways the earth currents were still perceptible, and how these distances were affected by the condition of the soil. In the meantime it is known that a variable current like that of an electric tramway has been detected telephonically by Strecker at a distance of 17 kilometres; that at Greenwich, 6·84 kilometres from the line of the South London Electric Railway, the disturbances of the horizontal force due to the railway vary between ·00004 and ·00007 C.G.S. unit, and of the vertical force between ·00004 and ·00009 C.G.S. unit; while at Washington, 420 metres from an electric railway, the disturbances of the horizontal amount to ·00010, and of the vertical force to ·0030 C.G.S. unit; and at Toronto, 120 metres from a line, to ·0012 and ·0037 C.G.S. unit respectively. The effect of such disturbances on magnetic measurements, which are at present made almost universally to ·00001 C.G.S. unit, will be readily understood, and when it is remembered what important results have followed a further increase of sensitiveness of the instruments at Potsdam, the limit of 15 kilometres seems small enough. While the author is anxious that no unnecessary hindrance should be placed in the way of tramway engineers, and assures them that the limit will be lowered as soon as experiment has shown them that it can be done with safety, he points out that they have a simple remedy in their own hands—*i.e.* to provide an insulated return.

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[1] For the complete paper see *Elektrotechnische Zeitschrift*, part 24, 1898.

2. *On the Magnetic Effects of Electric Railways at Berlin.*
By Dr. ESCHENHAGEN, *of Potsdam.*

Dr. Eschenhagen gave an account of the experiments which had been made in Berlin to determine the effects of the electric railways there, and the way in which they decreased with distance from the line. Although up to the present the results do not justify any general statement being made, Dr. Eschenhagen anticipates important results from the method he has now adopted of using large coils in series with delicate galvanometers as detectors of earth currents.

Papers on the subject were also contributed by Dr. C. Schott, Professor A. W. Rücker, Mr. W. H. Preece, F.R.S., Signor Luigi Palazzo, and Professor J. A. Fleming, F.R.S.

After the discussion the Permanent Committee passed the following resolution:—

'The Committee are of opinion that any sensible magnetic disturbance produced in a magnetic observatory by electric railways or tramways is seriously detrimental and may be fatal to the utility of the Observatory. They consider that special precautions should be taken to prevent such disturbances, and append as an example the provisions for the protection of the Kew Observatory inserted in a Bill passed by the English Parliament authorising the construction of an electric railway, the nearest point of which is to be at a distance of 1 kilometre from the Observatory.'

Clause for the Protection of Kew Observatory.

(1) The whole circuit used for the carrying of the current to and from the carriages in use on the railway shall consist of conductors which are insulated along the whole of their length to the satisfaction in all respects of the Commissioners of Her Majesty's Works and Public Buildings (in this section called 'the Commissioners'), and the said insulated conductors which convey the current to or from any of such carriages shall not at any place be separated from each other by a distance exceeding one-hundredth part of the distance of either of the conductors at that place from Kew Observatory.

(2) If in the opinion of the Commissioners there are at any time reasonable grounds for assuming that by reason of the insulation or conductivity having ceased to be satisfactory a sensible magnetic field has been produced at the Observatory, the Commissioners shall have the right of testing the insulation and conductivity upon giving notice to the Company, who shall afford all necessary facilities to the engineer or officer of the Commissioners or other person appointed by them for the purpose, and the Company shall forthwith take all such steps as shall in the opinion of the Commissioners be required for preventing the production of such field.

(3) The Company shall furnish to the Commissioners all necessary particulars of the method of insulation proposed to be adopted and of the distances between the conductors which carry the current to and from the carriages.

The following Papers were read:—

1. *On the Form of the Isomagnetic Lines in the Neighbourhood of the Volcano Etna.*[1] *By* LUIGI PALAZZO.

The author made absolute determination of the magnetic elements at a number of stations in Sicily and the neighbouring small island, and relative determinations in the district surrounding each station by means of small portable instruments. In three of the islands, the rocks of which were of volcanic origin, the variations of the elements were found to be large and irregular, even where the constitution of

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[1] For full details see the *Rendiconti d. Accad. d. Lincei*, December 5, 1897.

the ground was uniform and its surface plane. He expresses the results of his determinations by tracing the course of the isogonic line for 10° 30′, which passes through the west and is parallel to the lines in Italy, that for 10° which passes through the centre, and for 9° 30′ which passes through the east of the island and is profoundly modified by the presence of Etna, the isoclinal lines for 54°, 53° 30′, 53°, 52° 30′, 52°, which, with the exception of the 2nd and 3rd, passing respectively to the north and south of the volcano, are quite uniform, and the isodynamic line for ·252, which has nearly the same shape as the isoclinals. By comparison of his results with those obtained by Christini in 1882, the author concludes that the annual changes of the elements are :—

Declination	−5·6′
Inclination	−1·4′
Horizontal Intensity	+ ·000017

2. *On the Influence of Altitude above the Sea on the Elements of Terrestrial Magnetism.* *By* Dr. VAN RIJCKEVORSEL *and* Dr. W. VAN BEMMELEN.

The object of an investigation, which lasted from 1895–97, was to see if we could detect any influence of altitude above the sea on the magnetic elements. For various reasons, the Rigi was thought to be the mountain most suitable to our purpose, and in 1895 our observations were taken solely in order to discover if this mountain was really non-magnetic. We found that it was so.

In 1896 complete series of observations were taken, both on the mountain and at its base, at a large number of stations. The discussion of these observations seemed to show a very slight decrease of the horizontal and a somewhat larger, though still very slight, increase of the vertical component.

However, this result was very doubtful, because we found at the same time that the Rigi, though certainly non-magnetic as a mass, was covered all over with superficial centres of attraction, very weak, but still causing disturbances which seriously interfered with our results.

We resolved, therefore, to try again in 1897. In that year we took dips only at 198 stations, one of us always observing near the base of the mountain, the other, absolutely simultaneously with him, on the top or on the slopes. Although this time also the small, but numerous, local disturbances were a decided drawback for the discussion, the following results were obtained :

1. We think it is proved, that if there be an influence of the height above the sea on terrestrial magnetism it is so exceedingly small as to make it unfeasible to detect it with our present surveying instruments. Therefore it is decidedly unnecessary to take altitude into account in magnetic surveys.

2. If, nevertheless, it should ultimately be found that there is such an influence, however small, it is more likely that it would be an increase of the vertical force with altitude than anything else.

3. *On the Variation of Terrestrial Magnetic Force with Altitude.*[1]
By Professor J. LIZNAR.

The author has endeavoured to eliminate the effect of the nature of the soil and shape of the surface at any point, on the variation of the magnetic force with height above the surface at the point, by basing his calculations on the results for the 205 stations in Austria at which observations of the magnetic elements have been made. He divides the stations into three groups—the first including those of altitude less than 200 metres, the second between 200 and 400, and the third above 400 metres. The mean value of an element for the stations of a group, he considers to be the value of the element for the mean altitude of the group, almost

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[1] The complete paper is published in *Wiener Anzeiger*, 1898, p. 168.

completely freed from local effects. Taking these values for the three mean stations, he finds the increase of the elements per kilometre of ascent to be as follows:—

North component	−·00034 C.G.S.	Horizontal force	−·00029 C.G.S.
West "	+·00029 "	Declination	+5·03′
Vertical "	−·00064 "	Dip	−0·65′

The variations calculated on the assumption that the earth is a uniformly magnetised sphere are much smaller, and the author considers that the discrepancy arises from the fact that part of the magnetic potential of the earth is due to an external source.

Extracts from the Report of the Permanent Committee on Terrestrial Magnetism and Atmospheric Electricity to the International Meteorological Conference.

Constitution of the Committee.

The Committee on Terrestrial Magnetism and Atmospheric Electricity appointed at Paris in September 1896 consisted of eight members. These gentlemen found that it was desirable to add to their number by co-option, and the constitution of the Committee is now as follows:—

Appointed at Paris: Professor Rücker (President), Professor Eschenhagen, Professor Liznar, M. Th. Moureaux, Sig. L. Palazzo, Dr. Paulsen, Dr. van Rijckevorsel, General Rykatcheff.

Co-opted: Dr. Bauer, Professor W. von Bezold, Sig. Brito-Capello, Dr. Carlheim-Gyllenskjold, Professor Mascart, Professor T. Mendenhall, Professor A. Schmidt, Dr. C. Schott, and Professor A. Schuster.

International Conference.

In consequence of a suggestion, made originally by Professor Schuster, that arrangements should be made for an International Conference of those interested in Terrestrial Magnetism, the Committee decided to summon such a conference; and the hospitable invitation of the British Association to hold the meeting in connection with that of the Association at Bristol (September 7–14, 1898) was accepted.

The details of the arrangements are described in the President's address.

Meetings of the Permanent Committee.

The Committee held meetings on September 7, 9, 12, and 13, at which the following resolutions were unanimously approved:—

A. Questions referred to the Committee by the International Meteorological Conference.

(1) The following resolution of M. Dufour (Report of Paris Conference, p. 30). 'In calculating monthly means, all days are to be taken into consideration. It is left open to each director to give in addition means calculated without taking disturbed days into account.'

This was approved by the Committee with the substitution of the words 'It is desirable' for the words 'It is left open to each director.'

The Committee were also of opinion that the quiet days chosen by the directors of the different observatories should be communicated to the President of the Permanent Magnetic Committee, and circulated by him, and also that it is desirable to inquire if it will be possible to select the same quiet days for the different observatories.

(2) The resolution proposed by Professor von Bezold and M. Mascart (Report, p. 31):—

'It is desirable to publish the monthly means of the components X, Y, Z, and, at least for the months of January and July, the differences dX, dY, dZ of the hourly means from the preceding means.'

In lieu of this the Committee adopted the following resolution:—'It is desirable to publish the monthly means of the Geographical Components of the Magnetic Force for each month, and also the differences between the hourly means for each month and the monthly means for that month.'

(3) The resolution proposed by General Rykatcheff (Report, p. 32):—'It is desirable for the progress in Terrestrial Magnetism that temporary observatories should be installed in certain localities, especially in tropical countries.'

On this subject a Report was prepared, at the request of the President, by Professor von Bezold and General Rykatcheff. For the Report, and the resolution passed by the Committee, see p. 743.

The Committee were informed by Dr. C. Schott that it was the intention of the Coast and Geodetic Survey of the United States to establish a magnetic observatory at Honolulu.

In the course of the discussion on the above resolution, the Committee also resolved:—3A. 'That it is desirable to point out that observatories at great distances from others should be provided with both absolute and self-registering variation instruments.'

(4) The question as to the relative advantages of long and short magnets, raised by M. Mascart at the Paris Conference (Report, p. 39). For the Report, and the resolution passed by the Committee, see p. 741.

B. Resolutions passed by the Committee on matters arising during the International Conference.

(1) Professor Eschenhagen made a statement to the Conference as to his recent investigations on minute disturbances made by very sensitive apparatus with a very open time scale.

In view of this statement, the Committee expressed their sense of the importance of the resolutions on this subject passed by the Paris Conference (Report, p. 35) and the hope that the principal observatories would carry out simultaneous observations of the character proposed.

M. Moureaux informed the Committee that preparations for such observations were already complete in the observatory at Parc St. Maur.

The Committee took note of the statement that Professor Eschenhagen would be willing to give information as to the construction of the instruments used by him.

(2) The Committee also passed the following resolution:—'The Committee is of opinion that the early establishment of a magnetic observatory at the Cape of Good Hope provided with absolute and self-registering variation instruments would be of the highest utility to the science of Terrestrial Magnetism, especially in view of the Antarctic expeditions which are about to leave Europe, and that the observatory should be established at such a distance from electric railways and tramways as to avoid all possibility of disturbance from them.'

Directions were given that the proper steps should be taken to obtain the approval of the British Association for this resolution, with the request that, if approved, it should be forwarded to the Colonial Government.

(3) On the motion of Professor Adolph Schmidt, the Committee resolved:—'That it is desirable that magnetic observations taken in regions not included in a magnetic survey should be repeated from time to time, care being taken to secure the identity of the point of observation.'

(4) Professor Eschenhagen was requested to draw up a detailed scheme for the exchange between the various observatories of the curves of the self-registering variation instruments taken during important magnetic storms, and to lay the scheme before the next meeting of the Conference.

(5) With reference to certain inquiries which Professor Eschenhagen suggested

should be addressed to the Directors of Magnetic Observatories, the Committee was of opinion that, although it would be outside the scope of their duties to make the inquiries, it was desirable that the information should be collected and published.

(6) After the discussion on the magnetic disturbances introduced by electric railways and tramways, a resolution was adopted by the Committee, which is given on p. 759.

Future Organisation of the Committee.

The Committee took into consideration their own future organisation and passed the following resolutions: 'It is desirable that Terrestrial Magnetism should continue to be within the scope of the International Meteorological Conference, provided that—

(*a*) Invitations to attend that Conference are issued as widely as possible to Directors of Magnetic Observatories and to all students of Terrestrial Magnetism.

(*b*) That the Permanent Committee on Terrestrial Magnetism and Atmospheric Electricity, as established at the Paris Conference, be continued.

(*c*) That in future there shall be a Magnetic Section of the International Meteorological Conference, which shall elect or otherwise share in the appointment of a permanent Magnetic Committee.

(*d*) That the Magnetic Committee have power to summon an International Magnetic Conference at times other than those at which the whole of the International Meteorological (and Magnetic) Conference may meet.'

The Committee also consider that the President of the Permanent Magnetic Committee should only hold office between two successive meetings of the International Meteorological (and Magnetic) Conference.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—Professor W. E. Ayrton, F.R.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

I shall, I feel sure, have your sympathy if I begin by referring to the great loss which mathematics and physics have sustained in the untimely and disastrous death of Dr. John Hopkinson. It has often been said that he who leads in mathematics at Cambridge cannot follow the engineering life of Westminster. But a striking disproof of the generality of this statement was furnished by the brilliant work in the domains of theory and practice which was accomplished by him for whom we mourn.

Science has lost much, but the wife and mother has lost more, and to her, who in one day saw effaced so large a portion of her life, goes forth the expression of our grief and sorrow.

A year ago Section A was charmed with a Presidential Address on the poetry of mathematics, and if amongst those who entered the Physics lecture-theatre at Toronto on that occasion there were any who had a preconceived notion that mathematics was a hard, dry, repellent type of study, they must, after hearing Professor Forsyth's eloquent vindication of its charms, have departed convinced that mathematics resembled music in being a branch of the fine arts. Such an address, however, cannot but leave a feeling of regret amongst those of us who, engulfed in the whirl of the practical science of the day, sigh for the leisure and the quiet which are necessary for the worship of abstract mathematical truth, while the vain effort to follow in the footsteps of one gifted with such winning eloquence fills me with hopeless despair.

Section A this year is very fortunate in having its meetings associated with those of an 'International Conference on Terrestrial Magnetism and Atmospheric Electricity,' which is attended by the members of the 'Permanent Committee for Terrestrial Magnetism and Atmospheric Electricity' of the 'International Meteorological Conference.' It has been arranged that this Permanent Committee, of which Professor Rücker is the President, shall form part of the General Committee of Section A, and also shall act as the Committee of the International Conference, which will itself constitute a separate department of Section A. For the purpose, however, of preparing a Report to the International Meteorological Conference, and for similar business, this Permanent Committee will act independently of the British Association.

My first duty to-day, therefore, consists in expressing the honour and the very great pleasure which I feel in bidding you, members of the International Conference, most heartily welcome.

Among the various subjects which it is probable that the Conference may desire to discuss, there is one to which I will briefly refer as I am able to do so in a triple capacity. The earth is an object of much importance, alike to the terrestrial magnetician, the telegraph electrician, and the tramway engineer; but while the first aims at observing its magnetism, and the second rejoices in the absence of the earth currents which interfere with the sending of messages, the third seems bent on converting our maps of lines of force into maps of lines of tramway.

It might therefore seem as if electric traction—undoubtedly a great boon to the people, and one that has already effected important social developments in America and on the continent of Europe—were destined in time to annihilate magnetic observatories near towns, and even to seriously interfere with existing telegraph and telephone systems. Already the principle of the survival of the fittest is quoted by some electrical engineers, who declare that if magnetic observatories are crippled through the introduction of electric tramways, then so much the worse for the observatories. And I fear that my professional brethren only look at me askance for allowing my devotion to the practical applications of electricity to be tainted with a keen interest in that excessively small, but none the less extremely wonderful, magnetic force which controls our compass needles.

But this interest emboldens me to ask again, Can the system of electric traction that has already destroyed the two most important magnetic observatories in the United States and British North America be the best and the fittest to survive? Again, do we take such care, and spend such vast sums, in tending the weak and nursing the sick because we are convinced that they are the fittest to survive? May it not perhaps be because we have an inherent doubt about the justness of the survival of the strongest, or because even the strongest of us feels compelled to modestly confess his inability to pick out the fittest, that modern civilisation encourages *not* the destruction but the preservation of what has obvious weakness, on the chance that it may have unseen strength?

When the electrical engineer feels himself full of pride at the greatness, the importance, and the power of his industry, and when he is inclined to think slightingly of the deflection of a little magnet compared with the whirl of his 1,000 horse-power dynamo, let him go and visit a certain dark store-room near the entrance hall of the Royal Institution, and, while he looks at some little coils there, ponder on the blaze of light that has been shed over the whole world from the dimly-lighted cupboard in which those dusty coils now lie. Then he may realise that while the earth as a magnet has endured for all time, the earth as a tramway conductor may at no distant date be relegated to the class of temporary makeshifts, and that the raids of the feudal baron into the agricultural fields of his neighbours were not more barbarous than the alarms and excursions of the tramway engineer into the magnetic fields of his friends.

A very important consideration in connection with the rapid development of physical inquiry is the possibility of extending our power of assimilating current physical knowledge. For so wide have grown the limits of each branch of physics that it has become necessary to resort to specialisation if we desire to widen further the region of the known. On the other hand, so interlinked are all sections of physics that this increase of specialisation is liable to hinder rather than assist advance of the highest order.

An experimenter is therefore on the horns of a dilemma—on the one hand, if he desires to do much he must confine himself more or less to one line of physical research, while, on the other hand, to follow that line with full success requires a knowledge of the progress that is being made along all kindred lines. Already an investigator who is much engaged with research can hardly do more as regards scientific literature than read what he himself writes—soon he will not have time to do even that. Division of labour and co-operation have therefore become as important in scientific work as in other lines of human activity. Like bees, some must gather material from the flowers that are springing up in various fields of research, while others must hatch new ideas. But, unlike bees, all can be of the 'worker' class, since the presence of drones is unnecessary in the scientific hive.

Englishmen have long been at a disadvantage in not possessing any ready means of ascertaining what lines of physical inquiry were being pursued in foreign countries—or, indeed, even in their own. And, so far from making it easier to obtain this information, our countrymen have, I fear, until quite recently, been guilty of increasing the difficulty. For every college, every technical school in Great Britain—and their number will soon rival that of our villages—seems to feel it incumbent on itself to start a scientific society. And in accordance with the self-reliant character of our nation each of these societies must be maintained in absolute independence of every other society, and its proceedings must be published separately, and in an entirely distinct form from those of any similar body. To keep abreast, then, with physical advance in our own country is distinctly difficult, while the impossibility of maintaining even a casual acquaintance with foreign scientific literature lays us open to a charge of international rudeness.

There is, of course, the German *Beiblätter*; but the Anglo-Saxon race, which has spread itself over so vast a portion of the globe, is proverbially deficient in linguistic power, and consequently, till quite recently, information that was accessible to our friends on the Continent was closed to many workers in Great Britain, America, and Australia.

Influenced by these considerations, the Physical Society of London, in 1895, embarked on the publication of abstracts from foreign papers on pure physics, and, as it was found that this enterprise was much appreciated, the question arose at the end of the following year whether, instead of limiting the journals from which abstracts were made to those appearing in foreign countries, and the papers abstracted to those dealing only with pure physics, the abstracts might not with advantage be enlarged, so as to present a *résumé* of all that was published in all languages on physics and its applications.

The first application of physics which it was thought should be included was electrical engineering, and so negotiations were opened with the Institution of Electrical Engineers. After much deliberation on the part of the representatives of the two societies, it was finally decided to start a monthly joint publication, under the management of a committee of seven, two of whom should represent the Institution of Electrical Engineers, two the Physical Society, and three the two societies jointly. 'Science Abstracts' was the name selected for the periodical, and the first number appeared in January of this year.

A section is devoted to general physics, and a separate section to each of its branches; similarly, a section is devoted to general electrical engineering, and a separate section to each of its more important sub-divisions. The value of 'Science Abstracts' is already recognised by the British Association as well as by the Institution of Civil Engineers, for those societies make a liberal contribution towards the expenses of publication, for which the Physical Society and the Institution of Electrical Engineers are responsible.

At no distant date it is thought that other bodies may co-operate with us, and we have hopes that finally the scheme may be supported by the scientific societies of many Anglo-Saxon countries. For our aim is to produce, in a single journal, a monthly record in English of the most important literature appearing in all languages on physics and its many applications. This is the programme—a far wider one, be it observed, than that of the *Beiblätter*—which we sanguinely hope our young infant 'Science Abstracts' will grow to carry out.

The saving of time and trouble that will be effected by the publication of such a journal can hardly be over-estimated, and the relief experienced in turning to a single periodical for knowledge that could hitherto be obtained solely by going through innumerable scientific newspapers, in many different languages, can only be compared with the sensation of rousing from a distracting and entangled dream to the peaceful order of wakeful reality.

I therefore take this opportunity of urging on the members of the British Association the importance of the service which they can individually render to science by helping on an enterprise that has been started solely in its aid, and not for commercial purposes.

The greatness of the debt owed by industry to pure science is often impressed on us, and it is pointed out that the comparatively small encouragement given by our nation to the development of pure science is wholly incommensurate with the gratitude which it ought to feel for the commercial benefits science has enabled it to reach. This is undoubtedly true, and no one understands better than myself how much commerce is indebted to those whose researches have brought them—it may be fame—but certainly nothing else. The world, however, appears to regard as equitable the division of reward which metes out tardy approbation to the discoverer for devising some new principle, a modicum of the world's goods to the inventor for showing how this principle can be applied, and a shower of wealth on the contractor for putting the principle into practice. At first sight, this appears like the irony of fate, but in fact the world thus only proves that it is human, by prizing the acquisition of what it realises that it stands in need of, and by valuing the possession of what it is able to comprehend.

Now, is there not a debt of which those who pursue pure science are in their turn equally forgetful—viz., the debt to the technical worker or to some technical operation for the inception of a new idea? For purely theoretical investigations are often born of technics, or, as Whewell puts it, 'Art is the parent, not the progeny, of science; the realisation of principles in practice forms part of the prelude as well as of the sequel of theoretical discovery.' I need not remind you that the whole science of floating bodies is said to have sprung from the solution by Archimedes of Hiero's doubt concerning the transmutation of metals in the manufacture of his crown. In that case, however, it was the transmutation of gold into silver, and not silver into gold, that troubled the philosopher.

Again, in the 'History of the Royal Society at the End of the Eighteenth Century,' Thomson says regarding Newton: 'A desire to know whether there was anything in judicial astrology first put him upon studying mathematics. He discovered the emptiness of that study as soon as he erected a figure; for which purpose he made use of one or two problems in Euclid. . . . He did not then read the rest, looking upon it as a book containing only plain and obvious things.'

The analytical investigation of the motion of one body round an attracting centre, when disturbed by the attraction of another, was attacked independently by Clairault, D'Alembert, and Euler, because the construction of lunar tables had such a practical importance, and because large money prizes were offered for their accurate determination.

The gambling table gave us the whole Theory of Probability, Bernoulli's and Euler's theorems, and the first demonstration of the binomial theorem; while a request made to Montmort to determine the advantage to the banker in the game of 'Pharaon' started him on the consideration of how counters could be thrown, and so led him to prove the multinomial and various other algebraical theorems. Lastly, may not the gambler take some credit to himself for the first suggestion of the method of least squares, and the first discussion of the integration of partial differential equations with finite differences contained in Laplace's famous 'Théorie Analytique des Probabilités?'

The question asked Rankine by James R. Napier regarding the horse-power which would be necessary to propel, at a given rate, a vessel which Napier was about to build, resulted in the many theoretical investigations carried out by Rankine on water lines, skin-friction, stream lines, &c. For, as Professor Tait has said, 'Rankine, by his education as a practical engineer, was eminently qualified to recognise the problems of which the solution is required in practice; but the large scope of his mind would not allow him to be content with giving merely the solution of those particular cases which most frequently occur in engineering as we now know it. His method invariably is to state the problem in a very general form, find the solution, and apply this solution to special cases.'

Helmholtz studied physiology because he desired to be a doctor, then physics because he found that he needed it for attacking physiological problems, and lastly mathematics as an aid to physical research. But I need not remind you that it is his splendid work in mathematics, physics, and physiology, and not his success in ministering to the sick, that has rendered his name immortal.

Did not Kepler ask: 'How many would be able to make astronomy their business if men did not cherish the hope of reading the future in the skies?' And did he not warn those who objected to the degradation of mingling astrology with astronomy to beware of 'throwing away the child with the dirty water of its bath?' Even now, may we not consider all the astronomical research work done at the Royal Observatory, Greenwich, as a by-product, since the Observatory is officially maintained merely for the purposes of navigation? And are there not many of us who feel assured that, since researches in pure physics and the elucidation of new physical facts must quite legitimately spring from routine standardising work, the most direct way—even now at the end of the nineteenth century—of securing for the country a National Physical Laboratory is to speed forward a Government Standardising Institute?

Lastly, as you will find in Dr. Thorpe's fascinating 'Life of Davy,' it was the attempt to discover the medicinal effect of gases at the Pneumatic Institution in this city that opened up to Davy the charm of scientific research. And, indeed, the Royal Institution itself, the scientific home of Davy, Faraday, Tyndall, Rayleigh, and Dewar, owes its origin to Romford's proposal 'for forming in London by private subscription an establishment for feeding the poor and giving them useful employment . . . connected with an institution for introducing and bringing forward into general use new inventions and improvements by which domestic comfort and economy may be promoted.'

Coming now to physics proper, there is one branch which, although of deep interest, has hitherto been much neglected. We possess three senses which enable us to detect the presence of things at a distance—viz., seeing, hearing, and smelling. The first two are highly cultivated in man, and, probably for that reason, the laws of the propagation of the disturbances which affect the eyes and the ears have been the subject of much investigation, whereas, although to many animals the sense of smell is of far greater importance than those of seeing or hearing, and although, even in the human brain, a whole segment—a small one in modern man, it is true—is devoted to the olfactory fibres, the laws of the production and propagation of smell have received practically no attention from the physicist. For some time past it has, therefore, seemed to me to be of theoretical and practical importance to examine more fully into the physics of smell. Various other occupations have hitherto prevented my advancing much beyond the threshold of the subject, but, as it seems to me to open up what is practically a new field of inquiry for the physicist, I take this opportunity of putting on record some facts that have been already elucidated.

Various odoriferous substances have been employed in the experiments, and for several of these I am indebted to Mr. W. J. Pope. Although the physicist has been allowing the mechanical side of the subject to lie dormant, the chemist, I find, has been analysing flowers and other bodies used in the manufacture of scents, and then synthetically preparing the odoriferous constituents. In this way, Mr. Pope informs me, there has been added to the list of manufactured articles, during the past seven years or so, vanilin, heliotropin, artificial musk, irone and ionone, which give the perfume of the violet; citral, that of lemongrass; coumarin, that of hay, and various others; and he has kindly furnished me with specimens of several of these artificial scents, together with other strongly-smelling substances.

If it be a proof of civilisation to retain but a remnant of a sense which is so keen in many types of dogs, then I may pride myself on having reached a very high state of civilisation. But with the present investigation in view this pride has been of a very empty character, since I have been compelled to reject my own nose as quite lacking the sensitiveness that should characterise a philosophical measuring instrument. The ladies of my family, on the contrary, possess a nasal quickness which formerly seemed to me to be rather of the nature of a defect, since, at any rate in towns, there are so many more disagreeable odours than attractive ones. But on the present occasion their power of detecting slight smells, and the repugnance which they show in the case of so many of them, have stood me in good stead, and made it possible to put before you the following modest contribution to the subject.

There is a generally accepted idea that metals have smells, since, if you take up a piece of metal at random, or a coin out of your pocket, a smell can generally be detected. But I find that, as commercial aluminium, brass, bronze, copper, German-silver, gold, iron, silver, phosphor-bronze, steel, tin, and zinc are more and more carefully cleaned, they become more and more alike in emitting *no* smell, and, indeed, when they are *very clean* it seems impossible with the nose, even if it be a good one, to distinguish any one of these metals from the rest, or even to detect its presence. Brass, iron, and steel are the last to lose their characteristic odour with cleaning, and for some time I was not sure whether the last two could be rendered absolutely odourless, in consequence of the difficulty of placing them close to the nose without breathing on them, which, as explained later on, evolves the characteristic 'copper' and 'iron' smell. But experiment shows that, when very considerable care is taken both in the cleaning and the smelling, no odour can be detected even with iron or steel.

Contrary, then, to what is usually believed, metals appear to have no smell *per se.* Why, then, do several of them generally possess smells? The answer is simple; for I find that handling a piece of metal is one of the most efficient ways of causing it to acquire its characteristic smell, so that the mere fact of lifting up a piece of brass or iron to smell it may cause it to apparently acquire a metallic odour, even if it had none before. This experiment may be easily tried thus:—Clean a penny *very carefully* until all sense of odour is gone; then hold it in the hand for a few seconds, and it will smell—of copper, as we usually say. Leave it for a short time on a clean piece of paper, and it will be found that the metallic smell has entirely disappeared, or, at any rate, is not as strong as the smell of the paper on which it rests. The smell produced by the contact of the hand with the bronze will be marked if the closed hand containing it be only opened sufficiently for the nose to be inserted, and it can be still further increased by rubbing the coin between the fingers.

All the metals enumerated above, with the exception of gold and silver, can be made to produce a smell when thus treated, but the smells evolved by the various metals are quite different. Aluminium, tin, and zinc, I find, smell much the same when rubbed with the fingers, the odour, however, being quite different from that produced by brass, bronze, copper, German-silver, and phosphor-bronze, which all give the characteristic 'copper' smell. Iron and steel give the strong 'iron' smell, which, again, is quite different from that evolved by the other metals. In making these experiments it is important to wash the hands carefully after touching each metal to free them from the odour of that metal. It is also necessary to wait for a short time on each occasion after drying the hands, since it is not until they become again moist with perspiration that they are operative in bringing out the so-called smell of metals.

That the hands, when comparatively dry, do not bring out the smell of metals is in itself a disproof of the current idea that metals acquire a smell when slightly warmed. And this I have further tested by heating up specimens of all the above-mentioned metals to 120° Fahrenheit, in the sun, and finding that they acquire no smell when quite clean and untouched with the hands.

Again, dealing with the copper group, or with aluminium, *no* smell is produced by rubbing any one of them with dry table-salt, strong brine, or with wet salt, provided that a piece of linen is used as the rubber; but if the finger be substituted for the linen to rub on brine, a smell is observed with copper and German-silver, this smell, however, being rather like that of soda; and, whether dry salt, brine, or wet salt be rubbed on aluminium, a smell is noticed if the finger be used as the rubber, this smell being very marked in the case of the brine or wet salt. Again, although even when linen soaked in brine, or having wet salt on it, is used to rub tin, iron, or steel, a faint smell is noticed, this is much increased when the finger is substituted for the piece of linen.

As a further illustration of the part played by the skin in causing metallic smells, it may be mentioned that the explanation of certain entirely contradictory results, which were obtained in the early part of the investigation, when linen soaked in strong brine was rubbed on aluminium, was ultimately traced to one layer of moist linen of the thickness of a pocket-handkerchief, allowing the finger to act through it, so that an odour was sometimes noticed on rubbing aluminium with the piece of linen soaked in brine. For it was found that when two or more layers of the same linen soaked in the same brine were employed to separate the finger from the aluminium during the rubbing no smell could be detected.

From the preceding it seems that the smell in these cases is evolved partly by contact with the finger, partly by the action of the solution of salt, and partly by the rubbing of the solid particles of salt against the metals. That the friction of solid particles against metals is operative in evolving smells is also illustrated by the smell noticed when iron is filed, or when aluminium, iron, or steel is cleaned with glass-paper or emery-paper in the air. Indeed, the smell thus evolved by aluminium Mrs. Ayrton finds particularly offensive. A slight smell is also noticed if iron or steel be rubbed in the air with even a clean piece of dry linen, and each specimen of the copper group, with the exception of the phosphor-bronze, which was tried in this way, gave rise to a faint, rather agreeable smell. No indication of odour could, however, be thus produced with aluminium or zinc when both the metals and the linen rubber were quite clean. It should, however, be borne in mind that all these experiments, where very slight smells are noticed, and especially when the odour rapidly disappears on the cessation of the operation that produced it, are attended with a certain amount of doubt, for the linen rubber cannot be freed from the characteristic smell of 'clean linen,' no matter how carefully it may be washed.

Before, then, a metal can evolve a smell, chemical action must apparently take place, for rubbing the metal probably frees metallic particles, and facilitates the chemical action to which I shall refer. All chemical actions, however, in which metals take part do not produce smell; for example, no smell but that of soda, or of sugar, respectively, can be detected on rubbing any single one of the series of metals that I have enumerated with a lump of wet soda, or a lump of wet sugar, although chemical action certainly takes place. Again, no metallic smell is observable when dilute nitric acid is rubbed on copper, German-silver, phosphor-bronze, tin, or zinc, although the chemical action is very marked in the case of some of these metals. Weak vinegar or a weak solution of ammonia is also equally inoperative. On the other hand, merely breathing on brass, copper, iron, steel, or zinc, which has been rendered practically odourless by cleaning, produces a very distinct smell, while a very thin film of water placed on iron or steel evolves a still stronger odour. Such a film, however, produces but little effect with any of the metals except these two; and if the whole series is lightly touched in succession with the tongue, the iron and steel smell as strongly as when breathed on, the German-silver more strongly than when breathed on or covered with a water film, and the other metals hardly at all.

Now, as regards the explanation of these metallic smells, which have hitherto been attributed to the metals themselves. This, I think, may be found in the odours produced when the metals are rubbed with linen soaked in dilute sulphuric acid. For here, apart from any contact of the metal with the skin, the aluminium, tin, and zinc are found to smell alike; the copper group also smell alike, and the iron and steel give rise to the characteristic 'iron' smell, which, in this case, can be detected some feet away. Now, it is known that when hydrogen is evolved by the action of sulphuric acid on iron, the gas has a very unpleasant smell, and this, Dr. Tilden tells me, is due principally to the presence of hydrocarbons.[1] I have been therefore led to think that the smell of iron or steel when

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[1] I am informed that as all ordinary iron and steel contain, beside carbon, the elements phosphorus, sulphur, and silicon in quantities more or less minute, these substances, by combining with a portion of the liberated hydrogen, form compounds which have strong and characteristic odours, and, though in small quantity, contribute to the general effect. Of the hydrocarbons produced, the greater part consists of members of the paraffin series; but these are accompanied by more or less

held in the hand is really due to the hydrocarbons to which this operation gives rise; and it is probable that no metallic particles, even in the form of vapour, reach the nose or even leave the metal. Hence, although smell may not, like sound, be propagated by vibration, it seems probable that particles of the metal with which we have been accustomed to associate the particular smell may no more come into contact with the olfactory nerves than a sounding musical instrument strikes against the drum of the ear.

And the same sort of result may occur when a metal is rubbed, for, although in that case particles may very likely be detached, it seems possible that the function of these metallic particles may be to act on the moisture of the air, and liberate hydrogen similarly contaminated; and that in this case also it is the impurities which produce the smell, and not the particles of the metal with which we have been accustomed to associate it.

This view I put forward tentatively; and to further elucidate the matter I am about to begin a series of smell tests in various gases, artificially dried, with metals as pure as can be obtained.

I next come to the diffusion of smell. From the experience we have of the considerable distance at which a good nose can detect a smell, and the quickness with which the opening of a bottle of scent, for example, can be detected at a distance, I imagined that tubes not less than 15 or 20 feet in length would be required for ascertaining, even roughly, the velocity at which a smell travels. But experiment soon showed that when the space through which a smell had to pass was screened from draughts, it diffused with surprising slowness, and that feet could be replaced by inches in deciding on the lengths of the tubes to be used. These are made of glass, which is relatively easy to free from remanent smells.

When the room and tube had been freed from smell by strong currents of air blown through them, the tube was corked up at one end and taken outside to have another cork, to which was attached some odoriferous substance, inserted at the other end. The tube was now brought back to the odourless room, and placed in a fixed horizontal or vertical position, and the unscented stopper was withdrawn. As a rule, immediately after the removal of the stopper, a smell was observed, which had been transmitted very quickly through the tube by the act of corking up the other end with the stopper carrying the odoriferous material. This first whiff, however, lasted only a very short time, and then a long period elapsed before any further smell could be detected at the free end of the tube, whether that end was left open or closed between times. Finally, however, after, for example, about eighteen minutes in the case of a three-feet horizontal tube, having a large cotton-wool sponge saturated with oil of limes attached to one cork, the smell became definite and recognisable.

It would, therefore, appear that the passage of smell is generally far more due to the actual motion of the air containing it than to the diffusion of the odoriferous substance through the air. And, as a striking illustration of this, the following is interesting:—After the stopper had been in contact with the odoriferous substance for some time, it, of course, acquired a smell itself, which gradually spread in the room in which the experiment was made. And although this smell was due simply to the exposed part of the stopper, while the air inside the tube was at one end in contact with a mass of the odoriferous substance itself, the only place where the smell could *not* be detected during the course of the experiment was the space inside the open end of the glass tube. And, what seemed very surprising, it was found necessary, in several cases, to blow air through the room to clear out the smell which emanated from the *outside* of the stopper before the smell coming along the tube from the mass of odoriferous substance which was *inside* it at the other end could be detected. A further proof of the important part played by

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of unsaturated hydrocarbons belonging to the olefine and other series. In view of the fact that marsh gas at one end of the scale and paraffin wax at the other are both practically odourless, it is doubtful whether the liquid paraffins have much smell *when pure*, and it would, therefore, appear probable that the hydrocarbons which give the peculiar odour to the hydrogen escaping from iron may be the unsaturated compounds referred to above.

the motion of the air in diffusing smell was the fact that a strong smell at the free end of the tube could at any time be caused by merely loosening the stopper to which the scented sponge was attached; for sniffing at the free end then made a draught through the tube which brought the scent with it.

Further, although the glass tubes were coated outside with a thick layer of non-heat-conducting material, so as to check the formation of convection currents, due to difference in the inside and outside temperature caused by handling, the rate of travel of a smell from a given odoriferous material was found to be much quicker when the tube was vertical than when it was horizontal. But this, I am inclined to think, may have been caused by a small convection current which still was produced in spite of these precautions.

For, as suggested by Dr. Ramsay several years ago, a substance must have a molecular weight at least fifteen times that of hydrogen to produce a sensation of smell at all, and, further, since camphor, with which many of my experiments have been made, has, when vaporised, a density about five times that of the air, it seems unlikely that scent vapour should diffuse much more quickly upwards through a vertical column of air than through a horizontal one. At the same time, not only are the tests with the glass tubes very striking, but the general impression which exists that smells rise—indeed the very fact that the nasal channels of animals open downwards—tends to show that, whether due to draughts or not, smells have really a tendency to ascend. And the following result obtained with glass tubes closed at one end with stoppers carrying respectively camphor, menthol, oil of limes, &c., and at the other end with corks, is instructive on this point. For, on uncorking such a tube after it had been closed for a long time and allowing the odour to stream out of it through the open air towards the experimenter's face, it was always found that the tube had to be brought much closer when the scent stream was poured downwards than when she was in a vertical position and it was allowed to ascend, although, when it was poured downwards, the experimenter brought her nose into as favourable a position as possible for receiving the smell, by lying down with her head thrown well back.

As an illustration of the inefficiency of diffusion alone to convey a smell you will find that if you hold your breath, without in any way closing your nose either externally or by contracting the nasal muscles, you will experience no smelling sensation even when the nose is held close to pepper, or a strong solution of ammonia, or even when camphor in a minute tube is introduced high up into the nostril. Mere diffusion from the lower nasal cavity into the upper cannot apparently take place with sufficient ease to produce the sense of smell, so that an actual stream of air through the upper portion of the nose seems necessary even when the nose is a very sensitive one. This stream, for substances placed outside the nose, is produced by breathing *in*, no smell being detected while breathing *out*. On the other hand, if a substance be placed inside the mouth its flavour is recognised when the air is forced outwards through the nostrils—that is, at each expiration. Hence we may experience alternately two totally different smells by placing one substance outside the nose and the other in the mouth, the one smell being noticed in inhaling and the other in exhaling. And the latter can be increased by smacking the lips, which, I think, has really for its object the forcing of more air through the nostrils at each expiration.

Experiments on the propagation of smells in a vacuum have also been commenced in my laboratory, and the results are no less surprising than those obtained with the propagation in air. A U-tube, seven inches high, had the odoriferous substance placed inside it at the top of one limb, and a very good vacuum could be made by allowing mercury to flow out of the tube. Then the two limbs were separated by raising the mercury column, and, air being admitted at the top of the other limb, without its coming into contact with the odoriferous substance, the nose was applied at the top of this limb.

When liquids like ammoniated lavender smelling-salts, solution of musk, and amyl acetate were employed, and various devices were used for introducing the liquid, and preventing its splashing when it boiled on exhausting the air, it was found that the time that it was necessary to leave the two limbs connected for a smell to be just observable was reduced from a few minutes or seconds when the tube was filled with air to less than half a second for a good vacuum; with solid camphor it was reduced from twenty minutes to one second; and, when moist rose leaves were used, from fifty minutes to two seconds. But with solid particles of musk the time was not reduced below twenty minutes by taking away the air; while with dried lavender flowers and dried woodruff leaves no smell could be detected after the two limbs had been connected for many hours, and a good vacuum maintained. These experiments are, of course, somewhat complicated by variations in the amount of odorous surface exposed, but they seem to indicate that with these particular dried substances either the rate of evolution of the scent, or its rate of propagation, or both, are very slow even in a good vacuum.

I have also carried out some tests on the power of different substances to absorb various scents from the air. Lard, it is well known, is used to absorb the perfume from flowers in the commercial manufacture of scents, perhaps because it has little odour of its own, and because the scent can be easily distilled from it. But if lard, wool, linen, blotting-paper, silk, &c., be shut up for some hours in a box at equal distances from jasmine flowers, dried woodruff leaves, or from a solution of ammonia, I find that it is not the lard, but the blotting-paper, that smells most strongly when the articles are removed from the box. On the other hand, when solid natural musk is employed, it is the wool that alone acquires much smell, even after the box has been shut up for days.

Another noteworthy fact is the comparatively rapid rate at which grains of natural musk are found to lose their fragrance when exposed to the air. The popular statement, therefore, that a grain of musk will scent a room for years supplies but another example of the contrast between text-book information and laboratory experience.

The power of a smell to cling to a substance seems to depend neither on the intensity of the smell nor on the ease with which it travels through a closed space. Musk has but a faint smell, but the recollection of the greeting of a rich Oriental survives many washings of the hands. The smell of rose leaves, again, is but faint, and it travels very slowly through air in a tube; and yet the experiments on its propagation in the glass vacuum apparatus were rendered extremely troublesome by the difficulty experienced in removing the traces of the smell from the glass between the successive tests. Rubbing its surface was quite ineffectual, and even the mercury had to be occasionally shaken up with alcohol to free it from the remanent smell. In fact, we found, as Moore put it:

> 'You may break, you may shatter the vase if you will,
> But the scent of the roses will cling to it still.'

This absorption of scents by glass, and the ease with which I found that jasmine flowers could be distinguished from woodruff leaves, even when each was enclosed in a series of three envelopes specially prepared from glazed paper, and when many precautions were taken to prevent an odour being given to any of the envelopes in the operation of closing, as well as to prevent its diffusion through the joins in the paper, led me to try whether an actual transpiration through glass could be detected with the nose. For this object a number of extremely thin glass bulbs were blown from soda and from lead glass, so thin that they exhibited colours like a soap bubble, and felt, when gently touched, like very thin oiled silk, and after a little ammoniated lavender, amyl nitrite, ethyl sulphide, mercaptan, solution of musk, oil of peppermint, and propylamine had been introduced into them respectively, they were hermetically sealed, and placed separately in glass stoppered bottles.

In some cases, on removing the stopper from a bottle after many hours, a faint odour could be detected, but so, generally, could a minute flaw after much searching; the crack, however, being so slight that it did not allow sufficient passage of the air to prevent the bulb subsequently breaking, presumably from changes of atmospheric pressure. And in those cases where a smell was detected without any flaw being found in the glass, the subsequent breaking of the bulb put an end to further testing. The question, therefore, remains unanswered.

In presenting this brief introduction to the physics of smell, I have aimed at indicating the vast territory that waits to be explored. That it will be found to contain mines of theoretical wealth there can be no doubt; while it is probable that a luxuriant growth of technical application would spring up later on. Already, for example, Mrs. Ayrton unintentionally picks out inferior glass by the repugnance she shows at drinking water out of certain cheap tumblers. To conclude, I may say that one of my fondest hopes is that an inquiry into the physics of smell may add another to the list of wide regions of knowledge opened up by the theoretical physicist in his search for answers to the questions of the technical man.

The following Report and Papers were read:—

1. *Report on Comparing and Reducing Magnetic Observations.*

See Reports, p. 80.

2. *Lenses not of Glass.* *By* J. W. GIFFORD.

Glass passes light to $\lambda = 3612$, calcite to $\lambda = 2064$, and quartz to $\lambda = 1852$, the most refrangible line of aluminium. Seventy deviations were measured between $\lambda = 7951$ and $\lambda = 2147$. Over that range an uncorrected quartz lens $F = 11''$ gives $1{\cdot}76''$ of chromatic aberration; when corrected by calcite this may be reduced to $0{\cdot}24''$. A partially achromatised lens where error $= 0{\cdot}798''$ gives less spherical aberration and a flatter field. In this the achromatism curve is so nearly a straight line that a glass plate once tilted at the angle required, the spectrum may be photographed from $\lambda = 7951$ to $\lambda = 2147$ with good definition throughout.

There are only four elements known which give lines beyond the range of calcite. These lenses are therefore suitable for spark photography of projectiles.

The best lens for achromatism was calculated not from the dispersive powers, but from the refractions for $\lambda = 1852$, an imaginary deviation for calcite being obtained by graphical extrapolation. Fluor-spar corrected by quartz gives better achromatism.

3. *On the Articulation and Acoustics of the Spirate Fricative Consonants.*[1] *By* R. J. LLOYD, *D.Lit., M.A., F.R.S.E.*

The writer compared the results of his recent paper[2] with those of foreign observers.

The best German results[3] compare as under:—

—	*f*	*th*	*s*	*sh*	*ch* *in licht*	*ch* *in loch*	*h*
Trautmann . . .	1408	1584	1760	1760	3168	1408	—
Trautmann, 2nd res. .	—	—	—	+2376	—	—	—
Lloyd, neutral type	1408	1584	2570	2046	2500	1491	1320
Lloyd, range . . .	704–2816	880–2816	792–3168	792–3168	1760–2982	528–1760	287–2816
Lloyd, influence of neutral type . . .	very slight	slight	very strong	very strong	strong	moderate	nil

The differences between the first and third lines are probably personal for *s*, but national for *sh* and *ch*. They represent, in V.D. per. sec., the strongest sound heard in these consonants when articulated in isolation; and they are in each case created by the resonance of the oral cavity, before or behind the frictional passage. But this fixity of articulation and resonance is simply the combined result of convenience and habit. They may be easily made to vary through the wide ranges given in the fourth line; and in actual speech they do vary, under the influence of

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[1] *Neuere Sprachen*, vol. vii.

[2] *Roy. Soc. Edin.*, Proc. vol. xxii.

[3] Trautmann, *Sprachlaute*, 1885.

adjacent articulations, but with varying degrees of alacrity, as shown in the last lines of the table. Hence this resonance, though essential and very strong, does not differentiate these consonants from each other. Compared with other noises in Nature, they ranked as feebly differentiated hisses; but our cognition of their differences is sharpened by practice and heredity. A hiss may be differentiated by (1) the pressure behind it; (2) the length, width, or roughness of its aperture; (3) the resonance of the cavity from which (and into which, if any) it proceeds. Diagrams were shown to prove that the difference of *h* arises from the great length and width of the frictional passage; that the difference of *f* and *th* arises from the frictional passage of the latter being four times longer than the other, and the pressure greater; that the rest all differ from these in having some kind of fore-cavity, which greatly modifies and subdues the frictional noises; that *s* and *sh* differ from *ch* in having strong resonances proceeding from both the fore-cavity and the hinder-cavity, and reinforcing each other; and that *s* is distinguished chiefly from *sh* by a second friction, which takes place against the tips of the lower teeth and thus comes unsubdued to the ear.

4. *On the Conservation of Energy in the Human Body.*
By EDWARD B. ROSA *and* W. O. ATWATER.

The total energy taken into the body in the form of food is determined, and balanced against the total output. The experiments continued for a period of four to eight days, and the subject was in one case at rest while in the other he did eight hours of hard work each day. The output of energy consisted of—

1. Heat radiated from the body and also carried away as latent heat of water vapour given off from lungs and skin.
2. Mechanical work done.
3. Potential energy of materials contained in excreta and urine.

The heat was determined by use of the respiration calorimeter briefly described last year before Section A. (The *results* of experiments were not given then.)

The food, exhaled air, and excreta are all analysed, and a balance is found for carbon and nitrogen taken in and given off from the body.

The work done is compared with the total energy received and dissipated, and so the mechanical efficiency of the man as a machine is derived.

These are the first experiments, so far as we know, which give these results. The apparatus has been developed during six years of active work, involving a large amount of labour and expense, being supported by appropriations from the United States Government.

5. *On a Pneumatic Analogue of the Potentiometer.*
By W. N. SHAW, *F.R.S.*

The apparatus was designed to exhibit two air circuits, having one part of the path of the air common to both, but two separate aëromotive forces. This arrangement was obtained by having three openings to an otherwise closed box. One of the openings had a sliding shutter, and this formed the common portion of the two circuits. Each of the other openings was provided with a vertical glass tube, and a small gas jet, either in or below the tube, as the case may be; the hot air thus supplied gave rise to aëromotive forces. By adjusting the sliding shutter the flow in one tube could be made to go in the direction of the aëromotive force appropriate to that tube, or in the reverse direction, or could be arrested altogether by adjusting the position of the shutter. In this last-mentioned case, the one aëromotive force is exactly balanced by a fraction of the second and larger aëromotive force by the adjustment of resistances in a manner similar to the balancing of an electromotive force in the compensation method of measuring electromotive forces.

The direction of motion of the air in the tubes was identified by a specially designed detector of air-motion consisting of a very light mica flap attached to a knife edge, counterpoised for a suitable position. For exhibition to the section these detectors replaced the more sensitive rotating indicators which are adapted only for inspection from quite short distances.

The application of the experiment to the illustration of cases of air motion on a larger scale in certain examples of ventilation was pointed out.

FRIDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Comparison between Charging a Secondary Cell at Constant Potential and at Constant Current, more especially as regards Efficiency. By* A. A. CAHEN and J. M. DONALDSON.

The method of charging secondary cells at constant potential has only comparatively recently come into vogue, and the probable reason for its adoption now is the saving of time thereby effected.

Little, however, is known and nothing, as far as we are aware, has been published with regard to the efficiency and physical characteristics of the method.

The following tests were carried out to investigate these matters, and in order to make a fair comparison between charging at constant potential and charging at constant current a complete set of experiments by each method was tried on one cell.

This cell was of the Tudor type and had two positive plates (pasted) and three negative plates (unpasted). The size was that called 11 L.A., and its listed capacity, charging at 20 ampères and discharging at 36, was 108 ampère hours.

In order to get the true or working efficiency of the cell, it was charged and discharged many times without intermission, until charge and discharge curves obtained in consecutive experiments did not appreciably differ.

On February 24, 1898, charging at constant potential was begun, and, in all, 50 charges and discharges were carried out, the intervals between charge and discharge, discharge and charge being, on an average, one minute.

During the charge the potential difference between the terminals of the cell was kept constant at 2·51 volts, and charging was continued until the current had fallen to 10 ampères.

During the discharge the current was kept constant at 36 ampères, and the discharge was stopped when the P.D. had fallen to 1·82 volts.

The last charge was given on March 4, and on March 7, after a preliminary discharge, charging at constant current was started.

The cell was charged at a constant current of 20 ampères, and charging was continued in the first 22 tests until the P.D. had risen to 2·51 volts. During the twenty-third and following charges this limit was increased to 2·58 volts, in order to increase, if possible, the capacity, which was low in comparison with that obtained after a charge at constant P.D.

Discharge took place at a constant current of 36 ampères and was stopped when the P.D. had fallen to 1·82 volt.

Forty-six charges and discharges were carried out.

As, however, the capacity of the cell when charged at constant current was considerably less than that after a constant P.D. charge, we suspected that the heavy currents passed through the cell during the charges at constant P.D. had injured it, and so this method was again started to see if the capacity was still the same.

This was on March 17, after an interval of only half an hour.

Seven charges and discharges were sufficient to show that the capacity had not diminished, and these experiments brought the tests to an end.

Results obtained by Charging at Constant P.D.

Capacity and Efficiency.—The curves of charge and discharge drawn from the results of experiments 37–46 inclusive lie very near together, and the mean of the results was used in calculating the working efficiency.

The means of the results of experiments 13–49 inclusive, which do not differ much from the above, are also given.

The mean capacity and efficiencies from tests 6 and 7 of the second series of constant P.D. tests are also given, and it will be noticed that the energy efficiency is somewhat less than in first series.

Experiments	Ampère hrs. put in	Watt hrs. put in	Ampère hrs. taken out	Watt hrs. taken out	Quantity Efficiency per cent.	Energy Efficiency per cent.
1st Series—						
Mean of 37–46	91·89	230·4	86·07	163·5	93·7	71
„ 13–49	91·97	230·7	85·99	163 2	93·5	70·8
2nd Series—						
Mean of 6 and 7	93·60	235	85·2	161·0	91·0	68·5

The *density* of the acid varied from 1·159–1·175 in the first series of tests and from 1·154–1·174 in the second series of tests.

'Gassing,' or the brisk evolution of hydrogen bubbles from the negative plates, occurred just after the first rapid fall of current was over; this was when about two-thirds of the charging time had elapsed.

Resistance.—Only approximate figures can be given, as no special arrangements were made for taking the E.M.F. accurately at the moment of making or breaking the circuit.

During the last few tests of the second series the resistances were as below:—

Beginning of charge	End of charge	Beginning of discharge	End of discharge
0·0033 ohm.	0·01 ohm.	0·0043 ohm.	0·0033 ohm.

Shape of Curves.

Charging.—At the beginning of the charge the currents are, of course, very large, about 170 ampères being the usual initial current.

During the first three minutes of the charge a curious phenomenon always took place. The current fell by about 10 or 20 ampères, and then rose again very rapidly. After remaining fairly constant for about three minutes, the current falls very rapidly to about 40 ampères, and then drops much more gradually, becoming nearly constant at 10 ampères at the end of the charge.

This initial falling and rising again of the current we considered to be due to an excessive liberation of hydrogen by the large currents, causing a temporary increase in the back E.M.F. of the cell.

It did not occur in the first few experiments of the second series of tests at constant P.D., but appeared to a lesser extent in the last. The curves in these tests showed a steady falling off of current throughout.

Discharging.—The P.D. shows a very rapid initial drop, after which the curve bends off nearly at right angles, and then keeps quite level for a considerable time. After this the P.D. falls at an increasingly rapid rate. After a charge at constant current, the P.D. falls rapidly at first, and the change to the nearly level portion is not abrupt.

In the first case—*i.e.* after a constant P.D. charge—the rapid fall is practically over in the first three minutes, and after this the curve is nearly level; whereas in the other case the initial drop lasts three or four times as long, and the curve afterwards shows a gradual fall.

Charging at Constant Current.

By this method we obtained considerably smaller capacities, but higher efficiencies.

The working efficiency was obtained from the results given by experiments 44 and 45.

The mean of experiments 23–45 is also given.

Experiments	Ampère hrs. put in	Watt hrs. put in	Ampère hrs. taken out	Watt hrs. taken out	Quantity Efficiency per cent.	Energy Efficiency per cent.
44 and 45	68·35	152·1	65·25	123·1	95·4	81·0
23–45	—	—	—	—	95·1	81·0

The *Density* varied from 1·155–1·167, a less range than when charging at constant P.D.

Resistances.—

Beginning of charge	End of charge	Beginning of discharge	End of discharge
0·0038 ohm.	0·0077 ohm.	0·0041 ohm.	0·0034 ohm.

The shapes of the curves of charge and discharge at constant current are very well known, and need not be commented upon here.

Comparison of the two Methods of Charging.

What we have to compare in order to get an insight into the relative advantages and disadvantages of the two methods are:

1. The *discharge capacity,* or the energy we can get out of the cell.
2. The time *needed for charging.*
3. *The storage efficiency* or ratio of $\frac{\text{watts taken out}}{\text{watts put in}}$.
4. *The life of the cell.*

The first three are put into tabular form below, and we thus see that by charging at constant potential the time of charging is less than half that which is required if we charge at constant current, and that the capacity is 30 per cent. greater if the first method is employed, but that the energy efficiency is 10 per cent. less.

This loss of efficiency is probably due to the excessive heating caused by the large initial currents.

With regard to the life of the cell when charged at constant P.D., we can only say that after more than fifty charges and discharges the cell seemed in no way the worse.

The plates were not at all bent, neither was the amount of sediment at the bottom of the cell notably greater than at the beginning of the tests.

——	Time of Charging, minutes	Capacity		Efficiencies	
		Ampère hrs. taken out	Watt hrs. taken out	Quantity per cent.	Energy per cent.
Charging at Constant P.D. 2·51 volts. Charge till current = 10 ampères. Discharge at 36 ampères till P.D. 1·82 volt.	82	86	163	$93\frac{1}{2}$	$70\frac{3}{4}$
Charging at Constant Current 20 ampères till P.D. = 2·58 volts. Discharge at 36 ampères till P.D. 1·82 volt.	206	65·2	123	$95\frac{1}{2}$	81

2. *On a Magnifying Telephone.*[1] *By* Professor OLIVER LODGE, *F.R.S.*

For the purpose of 'calling up' in a system of magnetic induction telegraphy, and for other purposes, the author has devised a kind of telephone which emits a loud sound when stimulated by an exceedingly feeble alternating current. This is done partly by dispensing with iron in the moving part and utilising the motion of the coil instead, partly by aid of a large wooden sound-board, and partly by a combination of telephones and microphones in series, alternately electrically and mechanically connected, each microphone receiving a disturbance mechanically and passing it on electrically in a magnified condition to the next by reason of the fresh energy of its battery.

3. *On the Measurement of Small Differences in Resistance.*
By E. H. GRIFFITHS, *F.R.S.*

4. *The Dynamical Theory of Refraction, Dispersion, and Anomalous Dispersion.* *By* Lord KELVIN, *G.C.V.O.*

The dynamical theory of dispersion, as originally given by Sellmeier,[2] consisted in finding the velocity of light as affected by vibratory molecules embedded in ether, such as those which had been suggested by Stokes[3] to account for the dark lines of the solar spectrum Sellmeier's mathematical work was founded on the simplest ideal of a molecular vibrator, which may be taken as a single material particle connected by a massless spring or springs with a rigid lining of a small vesicle in ether. He investigated the propagation of distortional waves, and found the following expression (which I give with slightly altered notation) for the square of the refractive index of light passing through ether studded with a very large number of vibratory molecules in every volume equal to the cube of the wave-length

$$\mu^2 = 1 + m\frac{\tau^2}{\tau^2-\kappa^2} + m_{\prime}\frac{\tau^2}{\tau^2-\kappa_{\prime}^2} + m_{\prime\prime}\frac{\tau^2}{\tau^2-\kappa_{\prime\prime}^2} + \&c.,$$

where τ denotes the period of the light; κ, $\kappa_{\prime}$, $\kappa_{\prime\prime}$, &c., the vibratory periods of the embedded molecules on the supposition of their sheaths held fixed; and m, $m_{\prime}$, $m_{\prime\prime}$, &c., their masses. He showed that this formula agreed with all that was known in 1872 regarding ordinary dispersion, and that it contained what we cannot doubt is substantially the true dynamical explanation of anomalous dispersions, which had been discovered by Fox-Talbot[4] for the extraordinary ray in crystals of a chromium salt, by Leroux[5] for iodine vapour, and by Christiansen[6] for liquid solution of fuchsin, and had been experimentally investigated with great power by Kundt.[7]

Sellmeier himself somewhat marred[8] the physical value of his mathematical work by suggesting a distinction between refractive and absorptive molecules ('refractive and absorptive Theilchen'), and by seeming to confine the application of his formula to cases in which the longest of the molecular periods is small in comparison with the period of the light. But the splendid value of his formula for physical science has been quite wonderfully proved by Rubens, who, however,

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[1] See *Proc. Inst. Elec. Engineers*, Dec. 1898.

[2] Sellmeier, *Pogg. Ann.*, vol. cxlv. 1872, pp. 399, 520; vol. cxlvii. 1872, pp. 386 525.

[3] See Kirchhoff-Stokes-Thomson, *Phil. Mag.*, March and July 1860.

[4] Fox-Talbot, *Proc. Roy. Soc. Edin.*, 1870–71.

[5] Leroux, *Comptes Rendus*, vol. lv. 1862, pp. 126–128.

[6] Christiansen, *Pogg. Ann.*, vol. cxli. 1870, pp. 479, 480; *Phil. Mag.*, vol. xli. 1871 p. 244; *Annales de Chimie*, vol. xxv. 1872, pp. 213, 214.

[7] Kundt, *Pogg. Ann.*, vols. cxlii., cxliii., cxliv., cxlv. 1871–72.

[8] *Pogg. Ann.*, vol. cxlvii. 1872, p. 525.

inadvertently quotes[1] it as if due to Ketteler. Fourteen years ago Langley[2] had measured the refractivity of rock-salt for light and radiant heat of wave-lengths (in air or ether) from ·43 of a mikron to 5·3 mikrons (the mikron being 10^{-6} of a metre, or 10^{-4} of a centimetre), and without measuring refractivities further had measured wave-lengths as great as 15 mikrons in radiant heat. Within the last six years measurements of refractivity by Rubens, Paschen, and others, agreeing in a practically perfect way with Langley's through his range, have given us very accurate knowledge of the refractivity of rock-salt and of sylvin (chloride of potassium) through the enormous range of from ·4 of a mikron to 23 mikrons.

Rubens began by using empirical and partly theoretical formulas which had been suggested by various theoretical and experimental writers, and obtained fairly accurate representations of the refractivities of flint-glass, quartz, fluor-spar, sylvin, and rock-salt through ranges of wave-lengths from ·4 to nearly 12 mikrons.[3] Two years later further experiments extending the measure of refractivities of sylvin and rock-salt for light of wave-lengths up to 23 mikrons showed deviations from the best of the previous empirical formulas, increasing largely with increasing wave-lengths. Rubens then fell back[4] on the simple unmodified Sellmeier formula, and found by it a practically perfect expression of the refractivities of those substances from ·434 to 22·3 mikrons.

And now for the splendid and really wonderful confirmation of the dynamical theory. One year later a paper by Rubens and Aschkinass[5] describes experiments proving that radiant heat after five successive reflections from approximately parallel surfaces of rock-salt and again of sylvin is of mean wave-length 51·2 and 61·1 mikrons respectively. The formula which Rubens had given in February 1897, as deduced solely from refractivities measured for wave-lengths of less than 23 mikrons, made μ^2 negative for radiant heat of wave-lengths from 37 to 55 mikrons in the case of reflection from rock-salt, and of wave-lengths from 45 to 67 mikrons in the case of reflection from sylvin! (μ^2 negative means that waves incident on the substance cannot enter it, but are totally reflected).

5. *Continuity in Undulatory Theory of Condensational-rarefactional Waves in Gases, Liquids, and Solids, of Distortional Waves in Solids, of Electric Waves in all Substances capable of transmitting them, and of Radiant Heat, Visible Light, Ultra-Violet Light. By* Lord KELVIN, *G.C.V.O.*

Consider the following three analogous cases:—I. mechanical, II. electrical, III. electromagnetic.

I. Imagine an ideally rigid globe of solid platinum of 12 centimetres diameter, hung inside an ideal rigid massless spherical shell of 13 centimetres internal diameter, and of any convenient thickness. Let this shell be hung in air or under water by a very long cord, or let it be imbedded in a great block of glass, or rock, or other elastic solid, electrically conductive or non-conductive, transparent or non-transparent for light.

I. (1) By proper application of force between the shell and the nucleus cause the shell and nucleus to vibrate in opposite directions with simple harmonic motion through a relative total range of 10^{-3} of a centimetre. We shall first suppose the shell to be in air. In this case, because of the small density of air compared with that of platinum, the relative total range will be practically that of the shell, and

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[1] *Wied. Ann.*, vol. liii. 1894, p. 267. In the formula quoted by Rubens from Ketteler, substitute for $\mu\infty$ the value of μ found by putting $\tau=\infty$ in Sellmeier's formula, and Ketteler's formula becomes identical with Sellmeier's. Remark that Ketteler's 'M' is Sellmeier's '$m\kappa^2$,' according to my notation in the text.

[2] Langley, *Phil. Mag.*, 1886, second half-year.

[3] Rubens, *Wied. Ann.*, vols. liii. liv. 1894–95.

[4] Rubens and Nichols, *Wied. Ann.* vol. lx. 1896–97, p. 454.

[5] Rubens and Aschkinass, *Wied. Ann.*, vol. lxiv. 1898.

the nucleus may be considered as almost absolutely fixed. If the period is $\frac{1}{32}$ of a second, frequency 32 according to Lord Rayleigh's designation, a humming sound will be heard, certainly not excessively loud, but probably amply audible to an ear within a metre or half a metre of the shell. Increase the frequency to 256, and a very loud sound of the well-known musical character (C_{256}) will be heard.[1]

Increase the frequency now to 32 times this, that is to 8192 periods per second, and an exceedingly loud note 5 octaves higher will be heard. It may be too loud a shriek to be tolerable; if so, diminish the range till the sound is not too loud. Increase the frequency now successively according to the ratios of the diatonic scale, and the well-known musical notes will be each clearly and perfectly perceived through the whole of this octave. To some or all ears the musical notes will still be clear up to the G (24756 periods per second) of the octave above, but we do not know from experience what kind of sound the ear would perceive for higher frequencies than 25000. We can scarcely believe that it would hear nothing, if the amplitude of the motion is suitable.

To produce such relative motions of shell and nucleus as we have been considering, whether the shell is embedded in air, or water, or glass, or rock, or metal, a certain amount of work, not extravagantly great, must be done to supply the energy for the waves (both condensational and rarefactional), which are caused to proceed outwards in all directions. Suppose now, for example, we find how much work per second is required to maintain vibration with a frequency of 1000 periods per second, through total relative motion of 10^{-3} of a centimetre. Keeping to the same rate of doing work, raise the frequency to 10^4, 10^5, 10^6, 10^9, 10^{12}, 500×10^{12}. We now hear nothing; and we see nothing from any point of view in the line of the vibration of the centre of the shell, which I shall call the axial line. But from all points of view, not in this line, we see a luminous point of homogeneous polarised yellow light, as it were in the centre of the shell, with increasing brilliance as we pass from any point of the axial line to the equatorial plane, keeping at equal distances from the centre. The line of vibration is everywhere in the meridional plane, and perpendicular to the line drawn to the centre.

When the vibrating shell is surrounded by air, or water, or other fluid, and when the vibrations are of moderate frequency, or of anything less than a few hundred thousand periods per second, the waves proceeding outwards are condensational-rarefactional, with zero of alternate condensation and rarefaction at every point of the equatorial plane and maximum in the axial line. When the vibrating shell is embedded in an elastic solid extending to vast distances in all directions from it, two sets of waves, distortional and condensational-rarefactional, according respectively to the two descriptions which have been before us, proceed outwards with different velocities, that of the former essentially less than that of the latter in all known elastic solids.[2] Each of these propagational velocities is certainly independent of the frequency up to 10^4, 10^5, or 10^6, and probably up to any frequency not so high but that the wave-length is a large multiple of the distance from molecule to molecule of the solid. When we rise to frequencies of 4×10^{12}, 400×10^{12}, 800×10^{12}, and 3000×10^{12}, corresponding to the already known range of long-period invisible radiant heat, of visible light, and of ultra-violet light, what becomes of the condensational-rarefactional waves which we have been considering? How and about what range do we pass from the propagational velocities of 3 kilometres per second for distortional waves in glass, or 5 kilometres per second for the condensational waves in glass, to the 200,000 kilometres per second for light in glass, and, perhaps, no condensational wave? Of one thing we may be quite sure; the transition is continuous. Is it probable (if ether is absolutely incompressible, it is certainly possible) that the condensational-rarefactional

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[1] Lord Rayleigh has found that with frequency 256, periodic condensation and rarefaction of the marvellously small amount, 6×10^{-9} of an atmosphere, or 'addition and subtraction of densities far less than those to be found in our highest vacua,' gives a perfectly audible sound. The amplitude of the aërial vibration, on each side of zero, corresponding to this is $1{\cdot}27 \times 10^{-7}$ of a centimetre. *Sound*, vol. ii. p. 439 (2nd edition).

[2] *Math. and Phys. Papers*, vol. iii. art. civ. p. 522.

wave becomes less and less with frequencies of from 10^6 to 4×10^{12}, and that there is absolutely none of it for periodic disturbances of frequencies of from 4×10^{12} to 3000×10^{12}? There is nothing unnatural or fruitlessly ideal in our ideal shell, and in giving it so high a frequency as the 500×10^{12} of yellow light. It is absolutely certain that there is a definite dynamical theory for waves of light, to be enriched, not abolished, by electromagnetic theory; and it is interesting to find one certain line of transition from our distortional waves in glass, or metal, or rock, to our still better known waves of light.

I. (2) Here is another still simpler transition from the distortional waves in an elastic solid to waves of light. Still think of our massless rigid spherical shell, 13 centim. internal diameter, with our solid globe of platinum, 12 centim. diameter, hung in its interior. Instead of as formerly applying simple forces to produce to-and-fro rectilinear vibrations of shell and nucleus, apply now a proper mutual forcive between shell and nucleus to give them oscillatory rotations in contrary directions. If the shell is hung in air or water, we should have a propagation outwards of disturbance due to viscosity, very interesting in itself; but we should have no motion that we know of, appropriate to our present subject, until we rise to frequencies of 10^9, 10×10^{12}, 400×12^{12}, 800×10^{12}, or 3000×10^{12}, when we should have radiant heat, or visible light, or ultra-violet light proceeding from the outer surface of the shell, as it were from a point-source of light at the centre, with a character of polarisation which we shall thoroughly consider a little later. But now let our massless shell be embedded far in the interior of a vast mass of glass, or metal, or rock, or of any homogeneous elastic solid, firmly attached to it all round, so that neither splitting away nor tangential slip shall be possible. Purely distortional waves will spread out in all directions except the axial. Suppose, to fix our ideas, we begin with vibrations of one-second period, and let the elastic solid be either glass or iron. At distances of hundreds of kilometres (that is to say, distances great in comparison with the wave-length and great in comparison with the radius of the shell), the wave-length will be approximately 3 kilometres.[1] Increase the frequency now to 1000 periods per second: at distances of hundreds of metres the wave-length will be about 3 metres. Increase now the frequency of 10^6 periods per second: the wave-length will be 3 millim., and this not only at distances of several times the radius of the shell, but throughout the elastic medium from close to the outer surface of the shell; because the wave-length now is a small fraction of the radius of the shell. Increase the frequency further to 1000×10^6 periods per second; the wave-length will be 3×10^{-3} of a millimetre, or 3 mikroms,[2] if, as in all probability is the case, the distance between the centres of contiguous molecules in glass and in iron is less than a five-hundredth of a mikrom. But it is probable that the distance between centres of contiguous molecules in glass and in iron is greater than 10^{-5} of a mikrom, and therefore it is

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[1] *Math. and Phys. Papers*, vol. iii. art. civ. p. 552.

[2] For a small unit of length Langley, fourteen years ago, used with great advantage and convenience the word 'mikron' to denote the millionth of a metre. The letter *n* has no place in the metrical system, and I venture to suggest a change of spelling to 'mikrom' for the millionth of a metre, after the analogy of the English usage for millionths (mikrohm, mikro-ampère, mikrovolt). For a conveniently small corresponding unit of time I further venture to suggest 'michron' to denote the period of vibration of light whose wave-length in æther is 1 mikrom. Thus, the velocity of light in æther being 3×10^8 metres per second, the michron is $\frac{1}{3} \times 10^{-14}$ of a second, and the velocity of light is 1 mikrom of space per michron of time. Thus the frequency of the highest ultra-violet light investigated by Schumann (·1 of a mikrom wave-length, *Sitzungsber. d. k. Gesellsch. d. Wissensch. zu Wien*, cii. pp. 415 & 625, 1893) is 10 periods per michron of time. The period of sodium light (mean of lines D) is ·589212 of a michron; the periods of the 'Reststrahlen' of rocksalt and sylvin found by Rubens and Aschkinass (Wied. *Ann.* lxv. (1898) p. 241) are 51·2 and 61·1 michrons respectively.

No practical inconvenience can ever arise from any possible confusion or momentary forgetfulness in respect to the similarity of sound between michrons of time and mikroms of space.—K.

probable that neither of these solids can transmit waves of distortional motion of their own ponderable matter of so short a wave-length as 10^{-5} of a mikrom. Hence it is probable that if we increase the frequency of the rotational vibrations of our shell to one hundred thousand times 1000×10^6, that is to say, to 100×10^{12}, no distortional wave of motion of the ponderable matter can be transmitted outwards; but it seems quite certain that distortional waves of radiant heat in ether will be produced close to the boundary of the vibrating shell, although it is also probable that if the surrounding solid is either glass or iron these waves will not be transmitted far outwards, but will be absorbed, that is to say, converted into non-undulatory thermal motions, within a few mikroms of their origin.

Lastly, suppose the elastic solid around our oscillating shell to be a concentric spherical shell of homogeneous glass of a few centimetres, or a few metres, thickness and of refractive index 1·5 for D light. Let the frequency of the oscillations be increased to $5{\cdot}092 \times 10^{14}$ periods per second, or its period reduced to ·589212 of a michron: homogeneous yellow light of period equal to the mean of the periods of the two sodium lines will be propagated outwards through the glass with wave-length of about $\frac{2}{3} \times {\cdot}589212$ of a mikrom, and out from the glass into air with wave-length of ·589212 of a mikrom. The light will be of maximum intensity in the equatorial plane and zero in either direction along the axis, and its plane of polarisation will be everywhere the meridional plane. It is interesting to remark that the axis of rotation of the ether for this case coincides everywhere with the line of vibration of the ether in the case first considered; that is to say, in the case in which the shell vibrated to and fro in a straight line, instead of, as in the second case, rotating through an infinitesimal angle round the same line.

A full mathematical investigation of the motion of the elastic medium at all distances from the originating shell, for each of the cases of I. (1) and I. (2), will be found in a volume containing my Baltimore Lectures on 'Molecular Dynamics and the Wave-Theory of Light,' soon, I hope, to be published.

II. An electrical analogy for I. (1) is presented by substituting for our massless shell an ideally rigid, infinitely massive shell of glass or other non-conductor of electricity and for our massive platinum nucleus a massless non-conducting globe electrified with a given quantity of electricity. For simplicity we shall suppose our apparatus to be surrounded by air or ether. Vibrations to and fro in a straight line are to be maintained by force between shell and nucleus as in I. (1). Or, consider simply a fixed solid non-conducting globe coated with two circular caps of metal, leaving an equatorial non-conducting zone between them, and let thin wires from a distant alternate-current dynamo, or electrostatic inductor, give periodically varying opposite electrifications to the two caps. For moderate frequencies we have a periodic variation of electrostatic force in the air or ether surrounding the apparatus, which we can readily follow in imagination, and can measure by proper electrostatic measuring apparatus. Its phase, with moderate frequencies, is very exactly the same as that of the electric vibrator. Now suppose the frequency of the vibrator to be raised to several hundred million million periods per second. We shall have polarised light proceeding as if from an ideal point-source at the centre of the vibrator and answering fully to the description of I. (1). Does the phase of variation of the electrostatic force in the axial line outside the apparatus remain exactly the same as that of the vibrator? An affirmative answer to this question would mean that the velocity of propagation of electrostatic force is infinite. A negative answer would mean that there is a finite velocity of propagation for electrostatic force. This velocity, according to views regarding conceivable qualities of ether described in my article 'On the Reflection and Refraction of Light,'[1] might be greater than, equal to, or less than the velocity of light.

III. The shell and interior electrified non-conducting massless globe being the same as in II., let now a forcive be applied between shell and nucleus to produce rotational oscillations as in I. (2). When the frequency of the oscillations is moderate, there will be no alteration of the electrostatic force and no perceptible mag-

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[1] *Phil. Mag.*, vol. xxvi. 1888.

netic force in the air or ether around our apparatus. Let now the frequency be raised to several hundred million million periods per second; we shall have visible polarised light proceeding as if from an ideal point-source at the centre and answering fully to the description of the light of I. (2). The same result would be obtained by taking simply a fixed solid non-conducting globe and laying on wire on its surface approximately along the circumferences of equidistant circles of latitude, and, by the use of a distant source (as in II.), sending an alternate current through this wire. In this case, while there is no manifestation of electrostatic force, there is strong alternating magnetic force, which in the space outside the globe is as if from an ideal infinitesimal magnet with alternating magnetisation, placed at the centre of the globe and with its magnetic axis in our axial line.

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6. *Heat of Combination of Metals in the Formation of Alloys.*
By ALEXANDER GALT, *D.Sc.*

Hitherto few experiments have been made to determine the heat of combination of zinc with copper, or of other pairs of solid metals. Not only in connection with the theory of contact electricity in particular, but generally in respect to chemical affinities it is important that we should have some knowledge in regard to this question, and at the request of Lord Kelvin I have carried out the following experimental investigation in the physical laboratory of the University of Glasgow.

The method of procedure was to dissolve a known weight of an alloy and also under similar conditions the same weight of a mixture of the elements which are present in the alloy, the proportions taken being the same as those known to be in the alloy, and noting the initial and final temperature in each case. The heat of combination of the metals in the alloy may be estimated after noting the excess of the heat of solution of the mixture over that of the alloy.

A large number of preliminary experiments were made to determine the most suitable conditions for the investigation. The nature and strength of the solvent and its quantity for a given mass of the metals to be treated, keeping in view the advisability of obtaining a moderate range of thermometric readings and the necessity of minimising as far as possible the violence of the reaction between metals and solvent, had to be settled.

Messrs. Johnson, Matthey & Co., of London, kindly made for me and analysed five different alloys of practically pure zinc and copper, and they also supplied separate specimens of zinc and copper similar to those used in making the alloys. To facilitate solution the metals used were first reduced to powder by filing with a fine file. The method of experimenting finally adopted was carried out in detail as follows: One end of a short length of closed thin glass tubing was sealed to a very small glass bulb. Near the point of attachment there were, on opposite sides, two oval-shaped openings in the bulb. The glass tube was free to move up and down a certain distance through one of two holes bored through a short common cork. Special care being taken to see that the bulb was clean and dry, it was drawn down from the cork about six centimetres, and the cork fixed in a clamp. The filings (·5 gramme was the quantity always used in each of the experiments) were then most carefully inserted into the bottom of the bulb by one of the openings, and the bulb was then drawn up close to the cork. Through the other hole in the cork a very thin sensitive short-range thermometer, whose marked divisions correspond to 0·05° C., was passed. The cork carrying the bulb and attached tube and thermometer was then carefully fixed in the neck of a small flask of thin glass containing nitric acid of density 1·360. 60 cubic centimetres of which were used in nearly every one of these experiments. Holding the flask by the lip, it was gently shaken so as to give the acid a rotating motion; in this way the flask and contents soon attained a uniform temperature, which was carefully noted. The bulb was now plunged to near the bottom of the flask by quickly pushing down the glass tube to which it was attached; this plan effectually got rid of the difficulty of escaping fumes previously experienced. At the same instant the flask was inserted into an empty can, jacketed round the sides and bottom. Water in the jacket was heated by a Bunsen burner put below the can. A sensitive thermometer was suspended in the centre of the can, and the air there was maintained at a temperature about half a degree below the maximum temperature which would be attained by the solution in the flask. The time required for complete solution was about 55 seconds, the rotatory motion given to the liquid being kept up all the time. The moments of maximum temperature and complete solution were almost always nearly coincident in each experiment. The total weight of the whole apparatus (excluding acid and powder) was 20·5 grammes, and its water equivalent was taken as 3·5 grammes.

Alloy	Composition		Mean increase of temperature of solution per gramme of metal dissolved, expressed in degrees Centigrade			Heat of combination of the metals in the formation of one gramme of the alloy, expressed as a fraction of the heat of solution of one gramme of the mixture	Absolute amount of heat evolved by the combination of the metals in the formation of one gramme of the alloy, expressed in (gramme-water) heat units Centigrade
	Copper	Zinc					
	Percentage	Percentage	Mixture	Alloy	Difference		
A	25·14	74·86	21·08	21·08	0·00	0	0
B	38·38	61·32	19·29	18·44	0·85	$\frac{0{\cdot}85}{19{\cdot}29} = \frac{1}{22{\cdot}7}$	47
C	49·1	50·9	17·82	16·88	0·94	$\frac{0{\cdot}94}{17{\cdot}82} = \frac{1}{19}$	52
D	62·27	37·73	15·925	15·390	0·535	$\frac{0{\cdot}535}{15{\cdot}925} = \frac{1}{29{\cdot}8}$	30
E	75·225	24·775	14·09	13·68	0·41	$\frac{0{\cdot}41}{14{\cdot}09} = \frac{1}{34{\cdot}4}$	23

Alloy C contains the metals in their ordinary combining chemical proportions.

7. *A Platinum Voltmeter.* *By* Professor H. L. CALLENDAR, *M.A.*, *F.R.S.*

This is an instrument for measuring electric pressure or current by means of the increase of resistance of a fine platinum wire due to the heating effect of the current passing through it. It is most suitable for use as a voltmeter. Like other hot-wire voltmeters, it is equally available for direct or alternating currents. Unlike those instruments which depend upon increase of length with rise of temperature, the fine wire is not subjected to any strain. This makes it possible to use a much finer wire, securing greater delicacy and sensitiveness, and also consuming less power. The change of resistance is very large, being 100 to 200 per cent., and can be measured with great accuracy, whereas the change of length in the expansion voltmeter is very minute, and necessitates the use of magnifying gear, which is liable to introduce friction or strain. The platinum voltmeter, being simply a platinum resistance thermometer, constructed of very fine wire, is perfectly free from change of zero.

The changes of resistance of the fine wire are most conveniently indicated and recorded by means of the automatic recorder which is used for electrical thermometers. This apparatus was exhibited at the conversazione of the Royal Society. It consists essentially of a bridge-wire, forming part of a Wheatstone bridge or potentiometer, in which the galvanometer contact is automatically maintained at the balance point by means of a pair of motors controlled by the galvanometer. The recording pen is directly attached to the contact piece, and moves with it along a straight slide.

(The apparatus was exhibited in action, together with specimen records, and illustrative lantern-slides.)

The construction of the voltmeter is simply that of a platinum thermometer, exactly similar to those used for determining the temperature cycles of steam in the cylinder of a steam-engine, as described in the Proc. Inst. C. E. vol. cxxxi.

The sensitive part consists of a loop of pure platinum wire, one-thousandth of an inch in diameter, suitably protected in a tube or other enclosure.

On account of its great sensitiveness, and the large change of resistance, the instrument is best adapted for measuring small variations of voltage over a limited range, such as 100 to 120 volts. This gives a scale of 1 cm. per volt with a scale of approximately equal parts over the range covered.

8. *On Radiation from a Source of Light in a Magnetic Field.*
By Professor T. Preston, *F.R.S.*

9. *On the Discovery by Righi of the Absorption of Light in a Magnetic Field.* *By* Silvanus P. Thompson, *D.Sc.*, *F.R.S.*

An intense horizontal beam of sunlight or arc-light is passed along the axis of a Ruhmkorff's electromagnet. It is polarised at its entrance by a Nicol's prism, and by a second Nicol turned at right angles to the first it is extinguished at its exit. Let a sodium flame be now placed between the poles of the magnet. When the electromagnet is excited there appears in the field of vision a yellow spot of light, which, on being examined by a direct-vision spectroscope, shows the emission spectrum of sodium. If the observation is made without a spectroscope, and the analyser is turned, the yellow light does not disappear, but turns into a white light of increasing brightness. Its occurrence cannot therefore be accounted for on the basis of the Faraday phenomenon of the rotation of the plane of polarisation.

This result may be considered upon the following basis. Let n_1 be the frequency for a single absorption line in the spectrum of the body under examination. If the field-magnet is excited, then in consequence of an action the converse of that which exists in the Zeeman phenomenon the body no longer absorbs light of the frequency n_1, but instead absorbs two kinds of light—namely, one having a right-handed circular polarisation and of frequency n_2, the other having a left-handed circular polarisation of frequency n_3; the numbers n_2 and n_3 being so related that one of them is slightly less than n_1 and the other slightly greater. Optically the result is that there is now present circularly polarised light, some right-handed of one frequency, some left-handed of a different frequency, which, being circularly-polarised, cannot be cut off in any position of the analysing Nicol. The latter allows only the transmission of components parallel to its principal plane of section; and the yellow light which appears on the stimulation of the electromagnet is a proof that an effect converse to the Zeeman effect occurs in those cases where the body is absorbing instead of emitting light.

The intensity of the light which becomes visible on the stimulation of the magnetic field is obviously proportional to the intensity of the source of light from which emanates the beam that travels along the axis of the apparatus. A comparatively weak magnetic field suffices to produce the phenomenon. A field of intensity 300 C.G.S. units suffices; and with the ordinary pattern of Ruhmkorff magnet a single bichromate cell is adequate. The author has found no difficulty in repeating this fundamental effect in the laboratory of University College, Bristol.

If lithium is used, the light which appears is of course red; if thallium is used, the light is green.

Apart from its great sensitiveness the new method of observation possesses other features. What was said above about the beam having frequency n_1 also holds good for any and every other colour absorbed by the body, even in cases where these colours follow one another continuously and the absorption spectrum is no longer a line spectrum. The new method permits the proof to be given that the Zeeman effect occurs in bodies in which its occurrence could not be demonstrated in any other way. For, in order to carry out the observation of Zeeman in its original form, it was necessary that the spectrum, whether an emission or an absorption spectrum, should consist of sharply defined lines, since otherwise the splitting of the lines could not be demonstrated.

Righi has also observed the converse effect in nitric oxide. A small tube of glass, 32 mm. long and 15 mm. in diameter, is closed at its ends with thin discs of microscope glass cemented on with gutta-percha, and is provided with side-tubes by means of which it can be filled with dry nitrous fumes. This is placed between the poles of the magnet in a field of intensity about 2,000 C.G.S. units. A strong beam of white light is passed through the polariser at one end, then through the tube containing the nitrous fumes (in a direction parallel to the magnetic lines), then through the analyser, the latter being turned so as to cut off all the light. Looking back through the analyser the field appears absolutely dark. On turning on the exciting current there instantly appears *a green-blue light*, this being the tint which is complementary to the yellow-red that nitrous fumes usually show by transmission.

Applying a hand spectroscope one observes that the spectrum of this green-blue light is the complementary of that of the ordinary absorption spectrum; though in detail each dark 'line' would be replaced by two bright 'lines' close together. In fact, for every ray of frequency n_1 that would be absorbed by the substance when not in the magnetic field, there issue two rays of slightly differing frequencies n_2 and n_3; so that the light which appears when the field is made is practically identical (unless very great dispersion is applied to resolve it finally) with the light absorbed, however that light may be distributed in the spectrum.

If while looking at the green-blue light through the spectroscope the analyser is slightly turned, we get the ordinary spectrum of the yellow-red light due to absorption.

Here, then, we have the curious result that we can observe the emission-spectrum of a non-luminous gas.

This has been confirmed in the following experiment. A pellet of metallic sodium was gently heated in a current of dry hydrogen so that a non-luminous vapour of sodium was produced in a tube lying along the magnetic field. The arrangements were otherwise as before. When the analyser was crossed no light whatever was seen until the magnet was excited, when the ordinary radiation spectrum of sodium vapour (modified in reality by the doubling of each line) at once flashed out.

10. *On the Dissipation of Energy in the Dielectric of a Condenser.*

By EDWARD B. ROSA *and* ARTHUR W. SMITH.

The heating effect of an alternating E.M.F. upon the dielectric of a condenser is measured by a wattmeter, using a coil of wire in series with the condenser to give resonance and raise the voltage upon the condenser. The wattmeter measures the energy expended upon coil and condenser, the current being nearly in phase with the E.M.F. The coil loss is then deducted from the total to give the net energy expended upon the condenser. This is then divided by the energy stored to give the net loss, in per cent., and hence the efficiency.

The efficiency is defined as follows:—

$$\eta = \frac{\text{Energy stored—Energy dissipated}}{\text{Energy stored}}$$

and η is proved to be $1-\pi \cot \phi$, where ϕ is the angle between the current and E.M.F. for the condenser.

In a second series of experiments the condensers are placed in a calorimeter, especially designed for the purpose, and the heat measured while they are subjected to a measured E.M.F. at a known frequency. This gives the efficiency, which agrees with the previous work, though by a totally different method.

It is found that the percentage of loss in paraffin paper condensers is relatively small, varying with the temperature and condition of the paper before paraffining it. In *beeswax and rosin* condensers the energy lost is much greater, and increases as the temperature rises up to a maximum value and then decreases as the temperature rises further, until the dielectric begins to soften, then it increases rapidly. Exact numerical values are given for the losses.

11. *Hydrometers of Total Immersion.* *By* A. W. WARRINGTON, *M.Sc.*

The writer has made a series of experiments with the object of showing that the hydrometer becomes an instrument of scientific precision if it is modified so that when used it is totally immersed in the liquid.

Small ring-shaped platinum weights are slipped over the ungraduated neck of a glass hydrometer until the latter has nearly attained the specific gravity of the liquid to be tested. The temperature of the liquid is then slowly altered until the hydrometer and the liquid have exactly the same specific gravity.

With proper precautions this method gives results accurate to one in a million for temperatures from 0° to 40° C.

To determine the specific gravity of a solid a glass hydrometer is employed, which, in form, is not unlike a Nicholson hydrometer without its tray. Two experiments are made at approximately the same temperature, in one of which the hydrometer is weighted only with mercury, and in the other it is weighted with the solid together with the necessary amount of mercury. The results are correct to one in a hundred thousand.

SATURDAY, SEPTEMBER 10.

The Section was divided into two Departments.

The following Reports and Papers were read :—

DEPARTMENT I.—MATHEMATICS.

1. *Report on Tables of certain Mathematical Functions.*

See Reports, p. 145.

2. *The Mathematical Representation of Statistics.*

By Professor F. Y. EDGEWORTH.

1. Among methods of representing statistics of *frequency* Professor Karl Pearson's separation of a given group into two normal curves comes first. This method is based on a *vera causa* ; such composite groups are known to exist. An accurate fit, too, is obtained.

2. These advantages attach also to another method, which consists of a *second*—as the normal law, of a *first*—approximation to the result of numerous independent agencies co-operating. A given unsymmetrical group may commonly be generated by shifting each element of a certain normal curve to a distance which is the square of its original distance from a certain point. This method has two additional advantages : (*a*) It is easily worked, as the constants can be determined by *percentiles* (without taking *moments*) ; (*b*) the *correlation* between unsymmetrical observations may be obtained from the correlation of the generating normal surface.

3. A third class comprises formulæ of which the *a priori basis* is doubtful. An extreme instance—which, however, fits observations very well—is the juxtaposition, with a common greatest ordinate, of the halves of two different normal curves. Formulæ of the third class, obtained by substituting other functions for the *square* in the second method, are found to fairly represent statistics wholly unsymmetrical, as those of incomes, house valuations, &c.

3. *On the Use of Logarithmic Co-ordinates.* *By* J. H. VINCENT.

See Reports, p. 159.

4. *Stream Line Motion with Viscous Fluids in two Dimensions, and in three Dimensions. By* Professor H. S. HELE-SHAW, *LL.D.* See Reports, p. 136.

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5. *Mathematical Proof of the Identity of the Stream Lines obtained by means of a Viscous Film with those of a Perfect Flnid moving in two Dimensions. By* Sir G. G. STOKES, *F.R.S.* See Reports, p. 143.

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6. *On Graphic Representations of the two simplest cases of a Single Wave: (a) Condensational-rarefactional, (b) Distortional. By* Lord KELVIN, *G.C.V.O.*

For the simplest possible elementary wave of condensation and rarefaction, begin with an infinitely thin spherical shell containing air 1 per cent. denser than the air around it, and let the resistance of the shell be suddenly annulled. For the simplest possible elementary distortional wave, begin with a globular portion in the interior of a large homogeneous elastic solid, with proper application of tangential force to keep it turned round any diameter through half a degree of angle from its position of undisturbed equilibrium, and let the disturbing force be suddenly annulled.

Diagrams were exhibited to the Section by aid of which all the details of the two kinds of discontinuous wave thus produced were fully explained.

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7. *A New Method of Describing Cycloidal and other Curves.*
By Professor H. S. HELE-SHAW, *LL.D.*

A brief description of the instrument by which the curves are obtained was given. The instrument is described at length, together with certain of its practical applications, in a paper read before Section G, an earlier form having been shown in May of the present year at the Royal Society Soirée, although no printed description of it has hitherto appeared.

The essential points are:—

(1) The employment of auxiliary circles instead of the actual pitch circles of two sheets of cardboard which turn in connection with each other.

(2) A method by which the actual axis of rotation for each sheet is dispensed with, virtual axes only being employed.

By means of this instrument the describing pen or pencil used to mark out the cycloidal or involute curve can be made to draw the complete curve instead of only a portion of it as obtained by the ordinary methods, while the use of the virtual centres enables circles of any diameter to be employed, since it is no longer necessary to have a fixed centre for the cardboard within the limited range of a drawing-board or drawing-table. Hence, in the limit, the cycloid itself in which the circle rolls along a straight line, or an involute curve when the straight line rolls on a circle can be obtained, as well as ordinary epicycloidal and hypocycloidal curves, and the methods in which these curves are obtained are illustrated, as well as the rules for the adjustment of the instrument for any required conditions.

Since one well-known method of describing an ellipse is by means of a point attached to a circle rolling within another of twice its diameter, it is obvious that this instrument, the essential principle of which is the rolling of two imaginary pitch circles upon each other, can be applied to draw ellipses of any required eccentricity or magnitude.

Finally, the second feature of the new instrument above referred to, and which the author believes to be new, enables centres of curvature of two surfaces revolving on each other to be continuously varied.

The instrument was brought before the Section because it appears to offer to those interested in mathematics, and especially to those engaged in teaching the subject, a rapid means of describing rolling curves as well as envelopes.

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8. *The Recent History of the Theory of the Functions used in Analysis.*
By E. T. WHITTAKER.

Some recent advances in the theories of the known analytical functions are described in this paper. The problem of the expression of two variables, connected by any algebraic relation, as uniform automorphic functions of a new variable, is discussed; in this problem, Klein's generalised form of Lamé's equation, from which the functions of harmonic analysis may be derived, is of importance.

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9. *The Dynamical Explanation of certain observed Phenomena of Meteor Streams.* *By* Dr. G. JOHNSTONE STONEY, *F.R.S.*

The following are the principal results arrived at in this communication:—

Assiduous observation has brought to light several unexpected events in connection with the many meteor streams which intersect the earth's orbit. Some meteoric streams present differences in the duration and character of the showers of meteors in our atmosphere to which they give rise in successive years. The shower of meteors may be either brief or prolonged over many days; with some streams the radiant is, roughly speaking, stationary; in other cases it shifts across a portion of the sky in a variety of ways; the disposition of the shower about its maximum may be either symmetrical or unsymmetrical; and so on. Some of these events astronomers have succeeded in reconciling with the dynamical conditions under which meteors move; but there are others which still demand explanation, and the present paper is an inquiry with regard to these.

The meteors in a meteor stream are bodies of too small mass and too much separated to have any sensible influence on one another's motion. This simplifies the problem, for it justifies our treating each individual meteor as moving in its own orbit round the sun, disturbed only by the attractions of the surrounding planets, and assures us that whatever phenomena may present themselves, they must result from these independent motions of the individual meteors. So long as a meteor is at a distance from all the planets, their influence upon its motions may be investigated by the known methods of dealing with planetary perturbations. It is only when the meteor happens to pass close to some planet, whether the earth or another, that special treatment is required. The study of what then occurs is the aim of the present communication; and it is found that the unexplained phenomena of meteors are either the direct or the indirect outcome of the events which then develop themselves.

A sufficient investigation is possible by a method indicated by Laplace—a method of approximation which is indeed obvious. Laplace desires us to picture to ourselves a sphere of a certain size surrounding the planet as centre, and accompanying the planet along its orbit. Then a good approximation to what occurs may be obtained by regarding the meteor, while farther from the planet than the boundary of this sphere, as moving *in an orbit round the sun* under the influence of the sun's attraction only; and while inside the sphere as moving *relatively to the planet* under the influence of the planet's attraction only. This is equivalent to supposing that the meteor while in the close neighbourhood of the planet receives from the sun the same acceleration both in amount and direction as he impresses upon the planet. This is evidently an approximation to what actually occurs, and furnishes as good a general result as we can hope to obtain in the absence of definite information with regard to the elements of each separate meteoric orbit.

With this theorem of Laplace's we shall combine a consideration of which effective use was made by the late Professor Hubert A. Newton in the inquiry into the origin of periodic comets which is published in the Reports of former meetings of the British Association. He there pointed out that if a body of small mass crosses in front of a planet it draws the planet forwards, increases the planet's kinetic energy, and necessarily loses itself an equal amount of kinetic energy. This manifests itself by a slackening of its speed. The opposite effect is produced when a meteor passes behind a planet. Its speed is thereby increased. Accordingly, if a meteor from sub-stellar space—the space which lies between the solar system and the nearest stars—approaches the sun along a parabolic orbit, and happens to traverse Laplace's sphere and to pass in front of the planet, it will find itself, when it emerges from the sphere, moving with a speed too slow for parabolic motion, and accordingly its orbit round the sun is thenceforth elliptic and it becomes a permanent member of the solar system. When this happens to a group of meteors from cosmic space, instead of to an isolated meteor, a new periodic stream of meteors is added to the solar system.

Thus the great Leonid swarm may have been drawn into the solar system by having, while a nearly compact cluster, passed in front of the great planet Uranus —an event which probably happened (as was pointed out by Le Verrier) at the end of February or beginning of March in the year 126 of the Christian era.

This great meteor stream consists conspicuously of two classes of meteors, one or both of which are found in every meteor stream. These we may call ortho-meteors and clino-meteors. Ortho-meteors, when they are present, are those which form a stream the individual members of which pursue very nearly the same path. Accordingly those of them which are intercepted by the earth enter the earth's atmosphere on some definite day and from one direction. In the case of the Leonids they take 33¼ years to traverse their immense orbit, with deviations in the case of individuals from the mean periodic time which are so small that they all seem to be less than a week—that is, less than the 1,700th part of the mean periodic time. Yet these very small deviations have enabled the swarm of ortho-Leonids slowly to draw itself out along an arc of its orbit. until now, at the end of seventeen centuries, the stream is long enough to take more than two years to pass the earth's orbit when it comes round, which it does three times every century. It thus happens that on each return of the ortho-Leonids, the earth has time to come round twice to the place where the earth's orbit intersects the orbit of the meteors. The earth, therefore, now pierces the stream six times in a century, and, although in early times the number of its transits was fewer, this event cannot have occurred less than some 70 or 80 times.

On each such occasion the earth intercepts a vast number of meteors, but those that pass close enough to have their orbit sensibly changed must be much, probably 100 times, more numerous. All the ortho-Leonids thus affected become clino-Leonids. They are one class of clino-Leonids—namely, those which have been deflected by the earth into orbits which sensibly differ from the ortho-orbit. At the end of each revolution in their new paths they would, if there were no perturbations, return to the position close to the earth's orbit from which they started, so that the earth does not on account of what has happened lose its chance of encountering them on future occasions. But other parts of their new orbits will in general lie farther from the ortho-orbit, and the meteors moving in them will, moreover, have sensibly different periodic times. The variety of their periodic times will cause these clino-Leonids gradually to spread themselves round the whole ring, so that the earth encounters some of them every year and not only in the years when the ortho-Leonids return. Again, these clino-orbits having deviated from the ortho-orbit, perturbations will act differently upon them and will cause their nodes to advance, some faster and some slower than the node of the ortho-Leonids. This will enable some of them to encounter the earth for some days before and for some days after the ortho-date. By the ortho-date is meant that day in the middle of November when the earth reaches the node of the ortho-orbit.

So far, everything agrees with observation; but there is one other respect in which these earth-born clino-Leonids do not behave in the way observed. The shifting of the node would be accompanied in them by a corresponding shift of the radiant of about the same amount and in the same direction. This would involve an advance of the radiant which would amount to about 14° in longitude during the prolonged and feeble shower of clino-Leonids which has been observed. As no such considerable progression of the radiant has been observed, it is plain that these terrestrial clino-Leonids are not what have been chiefly recognised as Leonids.

We must turn, then, to the *planetary* clino-Leonids, to those other clino-Leonids which are such because they were acted on differently from the ortho-Leonids when the great planet Uranus drew the whole swarm into the solar system.

When we trace out the dynamical consequences of the conditions which then prevailed we find results which are everywhere in agreement with the observations. These planetary clino-Leonids are such as had been differently deflected by Uranus, and were thrown into slightly differing planes with slightly differing periodic times from the ortho-Leonids. The differences in periodic times have caused them to extend—one set of them backwards and the other forwards—round the whole ring, thus bringing some of them to the earth every year; while the variety of their planes and of the deflections which they suffered in them has had two effects. It causes the earth to encounter them for some days before and for some days after the ortho-date; and it occasions a forward shift of the radiant which seems to amount to about ten minutes daily. That the sparse shower presents itself for some days before the ortho-date is owing to the more deflected clino-Leonids having been now for seventeen centuries less acted on by perturbations than the ortho-Leonids. This has led to a shower rate at which their nodes have advanced along the ecliptic, and has also occasioned a gradual shift towards the westward of their radiant, which was originally displaced towards the east. Similarly, the clino-Leonids which were originally less deflected by Uranus than the ortho-Leonids, present themselves now at dates subsequent to the ortho-date, and reach us from radiants which originally lay west of the ortho-radiant, but have since been carried eastward by the quicker advance of their node. It is not likely that these shifts in opposite directions are exactly equal, but the difference is not such as to have attracted the notice of observers. It is therefore of small amount, but may perhaps be detected in observations which have been recorded. Thus in the list of (unfortunately very rough) determinations of radiant points, recently collected by Mr. Denning on page 20 of his pamphlet on the 'Great Meteoric Shower of November,' there are seven determinations which were made on days or groups of days preceding the ortho-date, and six upon days or groups of days after that epoch. The mean of the positions given by the determinations before the ortho-date is

$$\text{Æ}\ 148^\circ\ 43' \qquad \delta\ 22^\circ\ 51',$$

and the mean of the determinations after the ortho-date is

$$\text{Æ}\ 150^\circ\ 40' \qquad \delta\ 22^\circ\ 14',$$

which, so far as these observations can be trusted in a matter of so much delicacy, indicates a small shift in longitude towards the eastward accompanied by a slight change in latitude, which also is indicated by the theory.

Although it is plain that the clino-Leonids which have been recorded as Leonids have been chiefly, perhaps almost exclusively, the planetary clino-Leonids, it is certain that terrestrial clino-Leonids also exist, although they probably present themselves in our atmosphere in fewer numbers. They may be distinguished from the planetary clino-Leonids by the greater progress in longitude of their radiants, the position of which (within a degree) depends upon the date, advancing nearly a degree each day. They may probably have been already often observed; as it is not unlikely that they are some of those meteors which have been recorded as resembling Leonids, but which, nevertheless, have been supposed by observers to belong to other systems because their radiants were not in accordance with what has hitherto been supposed to be exclusively the radiant of the Leonids.

After dealing in detail with the phenomena of the great Leonid swarm, the investigation goes on to treat more briefly of other meteor streams, and indicates the dynamical conditions which presumably have given rise to several remarkable phenomena, such as the various other kinds of shifting radiants, the approximately stationary condition of some of them, the unsymmetrical distribution of some prolonged showers about their maximum, and other effects which have been observed.

10. *Survey of that part of the Scale upon which Nature works, about which Man has some Information.* *By* Dr. G. JOHNSTONE STONEY, *F.R.S.*

11. *The Imaginary of Logic.* *By* Professor G. J. STOKES.

Absence of a philosophical or logical theory of the imaginary. General adoption of the view that $\delta-1$ is uninterpretable in single or pure algebra. Paradoxical character of this position. How can what is essentially meaningless possess an important meaning in its extraneous use? Logical theory of the imaginary. Derivation from the law of duality. Application to De Moivre's theorem. 'The Carnot-D'Alembert paradox. Quaternions. Comparison of the Calculus of Boole's Laws of Thought with that of Grassmann's 'Ausdehnungslehre.' Relation of both to ordinary mathematics.

DEPARTMENT II.—METEOROLOGY.

1. *Report on the Ben Nevis Observatory.*—See Reports, p. 277.

2. *Report on Meteorological Photography.*—See Reports, p. 283.

3. *Report on Seismological Investigation.*—See Reports, p. 179.

4. *Interim Report on the Montreal Meteorological Observatory.* See Reports, p. 79.

5. *A Quantitative Bolometric Sunshine Recorder.*

By Professor H. L. CALLENDAR, *M.A.*, *F.R.S.*

This instrument is essentially a recording bolometer, in which the difference of temperature between a blackened and a bright platinum thermometer of equal resistance is recorded in pen and ink in the form of a continuous curve on a revolving drum. It differs from ordinary sunshine recorders in giving a strictly quantitative record of the quantity of heat received by the earth's surface, and not merely the number of hours of bright sunshine.

The sensitive part of the instrument, which is exposed to the radiation to be measured, consists of a pair of differential platinum thermometers wound on flat plates of mica, the one black and the other bright, and placed side by side in a horizontal plane so as to record the vertical component of the sunshine, on which the quantity of heat received by the surface of the earth mainly depends. The instrument gives a very complete record of the character of the sunshine, as well as of its intensity. The passage of small clouds, which would leave no trace on an ordinary burning glass or photographic record, is very clearly shown. It is also found that, when the sky is obscured by clouds of sufficient thickness to prevent any trace of burning on the ordinary cards, a very considerable percentage of the sun's heat may still penetrate.

The recording apparatus used is identical with that required for records of temperature, pressure, voltage, &c., and may be located in any convenient situation, at any required distance from the bolometer. It has been in use for more than a year at McGill College, Montreal, for obtaining records of sunshine, temperature, &c., and has been in regular operation at a distance of more than a mile from the observatory, where the recording apparatus is kept under the charge of the usual observatory assistants.

A simple form of planimeter is attached to the instrument when used for recording sunshine. The reading of the planimeter gives directly at any time the total quantity of heat received, and can be readily reduced to the number of equivalent hours of 'bright sunshine' by means of a suitable factor.

(The apparatus was exhibited in action, together with specimen records, and two illustrative lantern-slides.)

6. *Progress in the Exploration of the Air by means of Kites at Blue Hill Observatory, Massachusetts, U.S.A. By* A. LAWRENCE ROTCH, *S.B., A.M., Director.*

Since the report was presented to the Toronto Meeting of the Association great progress has been made in the work. The Hargrave Kite has been perfected by making it larger, more rigid, and relatively lighter, and by concaving the surfaces exposed to the wind the vertical component of the latter is increased. In general, these kites, with a short line, rise from 50° to 60° above the horizon and pull about one pound per square foot of lifting surface in a wind blowing 20 miles per hour. Elastic bridles diminish the angle of incidence of the wind as its pressure increases, and thereby enable the kites to fly in gales. A meteorograph, made by Mr. Fergusson, of the Observatory staff, which records the pressure of the atmosphere, the temperature, and relative humidity of the air and the velocity of the wind, weighs but 3 lbs. Since the use of wire and more efficient kites the mean height of the flights has been increased from about 1,000 feet in 1896 to above 7,000 feet during the past few months, and the height of 10,000 feet has six times been exceeded. The meteorograph reached an altitude of 11,086 feet above the hill in October 1897,[1] and its maximum altitude of 11,440 feet on August 26, 1898. A description of the apparatus employed and a discussion by Mr. Clayton, of the meteorological records obtained until February 1897, were published this year as an Appendix to the Blue Hill observations for 1896, in the 'Annals of the Astronomical Observatory of Harvard College,' vol. xlii, part 1. It is expected that the final discussion will be published by the Smithsonian Institution. In consequence of my report to the International Aëronautical Conference at Strasburg in April 1898, it was recommended that all central observatories should employ this method of investigation as being of prime importance for the advancement of meteorological knowledge.

7. *A New Form of American Kite. By* Professor A. SCHUSTER, *F.R.S.*

8. *Analogies between the Yearly Ranges of some Meteorological and Magnetic Phenomena. By* Dr. VAN RIJCKEVORSEL.

This is the second part of a paper read at the Toronto meeting, in which it was shown how exactly similar the yearly temperature curves are for a large part

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[1] See *Nature*, November 18, 1897, and February 17, 1898.

of Europe, and how the anomalies which these curves show may contribute in a large degree to the discovery of their origin.

In the diagram which was exhibited to the Section are plotted down six annual curves for temperature, air-pressure, rainfall, magnetic declination, and for the vertical and horizontal components of the earth's magnetic force. A portion of these curves are for Greenwich, others for two different stations in the Netherlands. It is now shown that all these curves, however dissimilar in their general directions, are exactly alike in their anomalies. Except in a very small number of instances, where the data at hand were not yet sufficient to make the phenomenon appear, every maximum or minimum in one curve seems to have its exact counterpart in every other curve, be it meteorological or magnetic. This is even the case for very small accidents of a curve, so that it is probable that it will ultimately prove to be true for every single feature of these curves, however insignificant.

These facts, in the first place, show once more how all the phenomena on the earth must be, to a large extent, governed by one and the same potent cause. But they also seem to give a valuable method for discovering, if not always the cause of meteorological phenomena, yet of the centre on the globe from which such a cause emanates.

It is also shown how the cause of a certain minimum in the temperature curves, indicating a sudden cooling in the last days of June all over the British Isles and part of Western Europe, what ever it may be, must have its seat to the west or north-west of the coast of Scotland, and at no great distance.

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9. *The Classification of Polydiurnal Weather Types in relation to the Prolongation of the Daily Forecast in Western Europe.* *By* DOUGLAS ARCHIBALD, *M.A., F.R.Met.Soc.*

The results of modern meteorological investigation, whether official or amateur, statistical or synoptic, have shown the existence of specific types of weather embracing wide areas and intervals of time varying from several days to months, and seasons which tend to produce persistence or recurrence of the more ephemeral changes connected with the passage of the smaller, temporary, and movable cyclonic and anticyclonic systems.

These large weather types may be roughly classified as:—(1) Seasonal or x monthly, and (2) y daily.

The former appear most clearly in tropical countries, such as India, where the y daily changes are small and where the summer season is always characterised by the formation of a permanent cyclonic area over Persia and North-Western India, with subsidiary low pressure troughs over the Ganges basin, round which the so-called S.W. monsoon circulates with a complete reversal of pressure conditions at the opposite season.

These normal conditions, expressed thus in general terms, are evidently the result of seasonal actions due to the direct influence of the sun on the Asiatic continent and Indian Ocean, and, stated thus, may be predicted to recur and form a large proportion of the seasonal forecast every year.

When, however, we descend from the general to the particular we find each year's S.W. and N.E. monsoon differ from that of every other year.

Superposed on the regular normal type is what may be termed the yearly seasonal abnormal type, corresponding to which both the intensity and shape of the seasonal cyclone and anticyclone and the accompanying weather vary. Such type, however, once initiated at the critical commencing month of the season, is found to persist more or less all through. This is the practical basis of the seasonal or x monthly weather forecast of the Indian Service, so ably worked by Mr. Eliot, F.R.S., at Simla.

In Europe the seasonal type, though still manifest, is not large enough in comparison with the y daily changes to enter in as a specific factor in the forecast.

On the other hand, the restriction of the forecast to 24 or 36 hours is unnecessarily arbitrary in view of the study of y daily types foreshadowed by the late

Hon. Ralph Abercromby and laboriously carried out by Professor Köppen and Professor J. Van Bebber in their recent discussion of 'Die isobaren Typen des nordatlantischen Ozeans und West-Europas.' [Hamburg, 1895.]

Abercromby, in his 'Principles of Forecasting by means of Weather Charts,' published by the Meteorological Council, classifies weather types under four heads —northerly, southerly, easterly, and westerly.

Professors Köppen and Van Bebber recognise twenty specific types of *y* daily weather.

A comparison of these with Abercromby's shows them to be all included in one or other of his four primary headings, of which they form specific sub-types.

The investigation further shows that:

(1) They admit of being more scientifically classified under the heads O oceanic, K continental, L littoral, P peripheral, N northerly, and S southerly. Sub-variations are denoted by suffixes, thus: O_s, O_k, O_l, O_n, &c.

(2) Certain groups occur preferably at each season, *i.e.* the seasonal type or tendency partly controls the formation of the *y* daily types.

(3) The intensity and paths of travelling high and low pressure systems vary with each type and season.

(4) Their effect in raising or lowering temperature and otherwise materially altering the weather is specifically shown by comparisons at such places as Hamburg and Munich.

(5) Their average duration is found to be about four days, and this figure is remarkably constant on the average for all the twenty species.

(6) There appears to be a fairly definite tendency on the part of certain types to succeed other types or to recur, such recurrence in some cases approximating to the seasonal permanence exhibited in the tropics.

In fine, a science of weather types is growing up by which even now the weather may, with due regard to a sudden change of type, be provisionally forecasted in general terms, and particularly for agricultural purposes, for *half a week* or *more.*

The present daily forecast in England is admirable for the purpose for which it was primarily instituted, viz. storm warning.

For agricultural purposes it is too short, while its assumption of precision in the matter of rainfall for each sub-division is not always warranted by the results. The author, therefore, suggests that in view of the hopefulness of the field unlocked by Professors Köppen and Van Bebber, steps be taken to compare the past weather maps of the British office with the types they have determined, and that a supplemental forecast be presently attached to the daily forecast, giving a more general forecast of conditions likely to continue for three or four days, based on the ascertained presence of a certain type over Western Europe and as far over the Atlantic as can be determined through the aid of arriving ship's logs.

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10. *The Rainfall of the South-Western Counties of England.*

By JOHN HOPKINSON, *F.R.Met.Soc., Assoc.Inst.C.E.*

The counties here considered as South-Western are Monmouth, Hereford, Worcester, Gloucester, Wilts, Dorset, Somerset, Devon, and Cornwall. They cover an area of 11,273 square miles, which is between one-fourth and one-fifth that of England, and nearly one-tenth that of the British Isles. The mean monthly rainfall for the ten years 1881 to 1890 at 72 stations in these counties has been calculated, and the mean annual rainfall at 113 stations, being one to the nearest 100 square miles in each county. Thus, for example, the annual rainfall of the smallest county, Monmouth (496 square miles), is deduced from the records of five stations, and that of the largest, Devon (2,586 square miles), from the records of twenty-six stations.

The monthly and annual means for each county and for the whole area at the 72 stations are as follows:—

Mean Rainfall in the South-Western Counties of England, 1881-1890.

	Monmouth, 5 stations	Hereford, 4 stations	Worcester, 5 stations	Gloucester, 8 stations	Wilts, 5 stations	Dorset, 5 stations	Somerset, 10 stations	Devon, 20 stations	Cornwall, 10 stations	Mean, 72 stations
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Jan. .	3·55	2·45	2·16	2·50	2·48	2·95	2·95	3·35	3·87	3·06
Feb. .	2·75	2·19	1·98	2·11	2·19	2·55	2·33	2·91	3·49	2·63
Mar. .	2·74	1·95	1·83	2·09	2·03	2·32	2·40	2·73	3·11	2·49
April .	2·29	1·95	1·84	1·97	2·17	2·43	2·53	2·34	2·60	2·30
May .	2·76	2·29	2·33	2·19	2·16	2·07	2·35	2·27	2·39	2·31
June .	2·44	2·34	2·29	2·38	2·50	2·40	2·40	2·19	2·36	2·33
July .	3·51	2·37	2·35	3·05	2·86	2·64	3·47	3·13	3·67	3·12
Aug. .	2·77	2·34	2·37	2·46	2·39	2·49	2·91	2·76	2·82	2·66
Sept. .	3·02	2·18	2·23	2·52	2·42	2·87	3·07	2·95	3·56	2·88
Oct. .	3·14	2·70	2·56	2·67	2·78	3·46	3·70	4·16	4·67	3·59
Nov. .	4·29	3·30	3·07	3·42	3·41	4·12	4·08	4·44	5·05	4·10
Dec. .	2·93	2·24	2·02	2·40	2·65	3·24	3·30	3·83	4·74	3·32
Year	36·19	28·30	27·03	29·78	30·04	33·54	35·49	37·06	42·33	34·79

The annual means at the 113 stations are—Monmouth (5 stations), 36·19 ins.; Hereford (9 stations), 28·64 ins.; Worcester (7 stations), 27·02 ins.; Gloucester (13 stations), 29·39 ins.; Wilts (14 stations), 29·71 ins.; Dorset (10 stations), 33·53 ins.; Somerset (16 stations), 35·54 ins.; Devon (26 stations), 37·24 ins.; and Cornwall (13 stations), 42·48 ins.; the mean for the whole area being 34·08 ins.

During the ten years 1881 to 1890 the rainfall in this part of England was rather less than that for the twenty-five years ending 1890 and that for the thirty years ending 1895. Twenty stations fairly distributed over the area give for the twenty-five years an annual mean of 1·2 inch more than for the ten years, and twelve stations give for the thirty years exactly the same excess over the ten years, so we may assume that the mean rainfall deduced for the ten years 1881 to 1890 is about an inch, or 3 per cent., less than it would have been had it been worked out for twenty-five or thirty years.

The mean for the 113 stations, one to each 100 square miles in each county, is no doubt more accurate for the decade 1881–90, as well for the whole area as for each county, than that for the 72 stations, but it is evident that the latter is much nearer the mark for the thirty years 1866–95, the true mean for the whole area for this period probably being about 35 inches per annum.

The rainfall in these counties follows the general rule for England of increase from east to west. Dividing them into three groups, N., S.E., and S.W., 22 stations for the northern group, Monmouth, Hereford, Worcester, and Gloucester, give an annual mean of 30·03 inches; 20 stations for the south-eastern group, Wilts, Dorset, and Somerset, give 33·64 inches; and 30 stations for the South-Western group, Devon and Cornwall, give 38·82 inches. In the first group the driest month is April, with a mean fall of 2·01 inches; in the second, the driest month is May, with a mean fall of 2·23 inches; and in the third, the driest month is June, with a mean fall of 2·25 inches. In each group the wettest month is November, with a mean fall of 3·51 inches in the first group; of 3·91 inches in the second; and of 4·65 inches in the third. From October to April and in July Worcester is the driest county; in May, Wilts; in June, Devon; and in August and September, Hereford. From September to April and in July Cornwall is the wettest county; in May, Monmouth; in June, Wilts; and in August, Somerset.

The mean annual rainfall at twelve stations, every county being represented by one or two, for the thirty years 1866 to 1895, in five-yearly periods, was as follows:—For the first lustrum, 1866–70, 35·76 inches; for the second, 1871–75, 39·02 inches; for the third, 1876–80, 40·15 inches; for the fourth, 1881–85, 38·25 inches; for the fifth, 1886–90, 33·07 inches; and for the sixth, 1891–95, 34·84 inches.

The memoir was accompanied by a map showing the position of the rainfall stations and their height above mean sea-level.

MONDAY, SEPTEMBER 12.

A discussion was held in conjunction with Section B on the Results of the Recent Solar Eclipse Expeditions.

The following Report and Papers were read:—

1. *Interim Report on Electrolysis and Electro-chemistry.*

See Reports, p. 158.

2. *Dilute Solutions. By* E. H. GRIFFITHS, *F.R.S.*

3. *Conductivity of Dilute Solutions. By* W. C. D. WHETHAM.

4. *Velocity of the Electricity in the Electric Wind.*
By Professor A. P. CHATTOCK.

It is shown that when an electric wind is produced by discharge in air from a point against an earth-connected metal plate, the momentum imparted to the air is proportional to the distance from point to plate. From this the author concludes, first, that the velocity of the electricity is directly proportional to the electrostatic field which moves it, and secondly, that there is no appreciable kick-off or reaction at the point.

Values are given for the velocity of the electricity relatively to the point and plate in unit electrostatic field and in various gases (not specially purified) at normal temperature and pressure—

	+	−	
Dry air	342	423	cm. per sec.
Hydrogen	1050	1150	„
Carbon dioxide	200	205	„

As it is shown that the velocity of the wind in which the electricity moves is negligible compared with that of the electricity itself, it follows that these values are those of the electricity carriers relatively to the gas through which they pass. Close to a sharp point it is probable that the actual velocity reached by the carriers exceeds 10^6 cm. per second.

5. *Dalton's Law. By* W. N. SHAW, *F.R.S.*

Discrepancies between the sum of the partial pressures of air or nitrogen and saturated vapour and the pressure of mixtures of air and saturated vapour indicating, *primâ facie*, a departure from Dalton's law were shown by Regnault[1] to exist for water vapour, the extent of the differences being on the average nearly half a millimetre.

Regnault himself in his classical paper on the pressure of vapours,[2] sought to

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[1] *Ann. de Chim.* [3] vol. xv.

[2] *Mém. de l'Institut*, vol. xxvi.

throw additional light on these discrepancies by examining the increase of pressure produced by adding ether or some other volatile liquid to an atmosphere, the pressure of which had been previously measured. In the course of these experiments, he concluded that he had satisfactorily ascertained the cause of the phenomena to be the condensation of the vapours on the vertical sides of the containing tube under a pressure of vapour less than the saturation pressure corresponding to the temperature. He regarded Dalton's law as being true in fact for a gas-filled space completely surrounded by a sufficiently thick layer of the evaporating liquid. In a vessel with solid vertical walls gravity prevents the formation of a layer of the required thickness on the vertical sides. This hypothesis was held to account for the fact that if the mixture were compressed, as in a Boyle's law tube, the pressure gradually diminished after the initial compression to a value less than that required by Dalton's law; in the case of ether about 10 mm. of pressure were missing on this account.

Such an hypothesis would give a satisfactory explanation of the phenomena if the sides of the glass vessel were gradually dissolved away by the liquid condensed on the sides, as, for example, would be the case if the tube were made of rock salt; but if the action between the glass sides and the vapour were merely a mechanical one, the supposed continuous evaporation of liquid from the horizontal surface and its return to the stock by condensation on the vertical sides and running down them would seem to contradict the principle of conservation of energy.

Regnault's explanation is the more difficult to accept if the density of the vapour be considered. Professor J. J. Thomson, in his 'Application of Dynamics to Physics and Chemistry,' has shown that the addition of air-pressure upon a liquid surface in contact with its saturated vapour ought to result in a slight additional evaporation causing a slightly increased density of vapour, and the experiments of the Author upon air at various degrees of saturation[1] indicated experimentally some slight increase of density beyond that required to correspond to the vacuum pressure, so that any apparent departure from Dalton's law could not be attributed to the want of mass of vapour in saturated air.

The point might be investigated by ascertaining experimentally the behaviour of a mixture of air and vapour under isothermal conditions in the neighbourhood of the point at which condensation begins to occur. At great rarefaction the mixture would behave as a perfect gas, and if the isothermal relation between p and $1/v$ were plotted on a diagram (with a suitable correction if necessary for the deviation of the air from Boyle's law) the curve obtained would be a straight line through the origin represented by $p = k \times 1/v$. At great concentration if Dalton's law were strictly true the relation would again be represented by a straight line, viz.:—

$$p = k' \times 1/v + p_v,$$

where k' is the Boyle's law constant for the contained dry air, and p_v is the saturation pressure of the vapour. This line would cut the vertical line $1/v = 0$, in the point distant p_v (*i.e* the theoretical saturation pressure) from the origin, and it would cut the line $p = 0$ in the point $1/v = -\frac{p_v}{k'}$. These two theoretical lines would meet if produced at an obtuse angle in the theoretical saturation point.

If, on the other hand, at the greater concentration there were a discrepancy from Dalton's law proportional to the total pressure and therefore represented by the relation,

$$p = k' \times 1/v + p_v - \lambda p,$$

the observations should still show a straight line not quite coinciding in direction with the theoretical line for Dalton's law, but cutting that line in the point on the horizontal axis $\left(-\frac{p_v}{k'}, 0\right)$ and cutting the vertical axis at a point distant $(1-\lambda)\,p_v$ from the origin.

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[1] *Phil. Trans.*, vol. clxxix. (1888), 'Report on Hygrometric Methods.'

A series of observations thus plotted would enable one to determine whether the actual behaviour of the mixture at higher pressures tended to approach to agreement with Dalton's law or some modification of it such as that suggested.

Regnault's observations include a series of determinations of the pressure and related volumes of mixtures of air and ether vapour for the temperature 7·7° C. They also show the dry-air pressures for the series of observed volumes. A diagram showing two sets of his observations was exhibited. The pressures varied between 600 and 1,400 millimetres. It was pointed out that for the observations at greater rarefactions the Boyle's law line was very strictly adhered to until the pressure reached 80 per cent. of saturation, then slight discrepancy in the direction of loss of pressure was indicated, increasing until it amounted to upwards of 10 millimetres for the theoretical saturation point; beyond that the discrepancy showed a slightly diminishing value. A straight line drawn to show a theoretical defect from Dalton's law amounting to λp, where $\lambda = \cdot 007$, agreed much more satisfactorily with the plotted observations.

The second series of observations made with a greater amount of ether showed the discrepancy from Dalton's law gradually vanishing with increased pressure.

It was pointed out that in drawing his conclusions Regnault had not taken account of the supersaturation of air which would result from compressing air even at a constant temperature in the absence of nuclei for condensation and the time that would be required for the gradual deposition of the excess of moisture upon the liquid surfaces exposed to it.

Moreover, it seemed most unlikely that if the presence of air caused a discrepancy of 10 mm. for a total pressure of 1,000 mm. the increase of the pressure to 1,400 mm. should do away with the discrepancy previously caused; in other words, the line connecting the observations and intersecting the theoretical line at the highest pressure recorded is antecedently improbable and unreal.

The conclusion drawn was that Regnault's explanation is probably an unreal one, and that an actual divergence from Dalton's law is indicated. The amount of the divergence, however, cannot be finally deduced from Regnault's observations, and must wait for a repetition of those or similar experiments, in which the errors which may be due to supersaturation are guarded against.

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6. *On the Determination of the State of Ionisation in Dilute Aqueous Solutions containing two Electrolytes: No. 2. By* Professor J. G. MacGregor, *Dalhousie College, Halifax, N.S.*

In the Report of last year methods were described of determining the ionisation coefficients in solutions containing two electrolytes, with or without a common ion, and with no mutual chemical action other than double decomposition; and a statement was given of tests of accuracy which had been applied to the coefficients thus obtained, by the employment of them for the calculation of the conductivity of the solutions. Since that date other tests have been applied by students in my laboratory, as follows:—E. H. Archibald has shown that the conductivity of solutions containing K_2SO_4 and Na_2SO_4 can be calculated within the limits of experimental error up to a total concentration of about 1 gr.-eq. per l. T. C. McKay has obtained the same result for solutions containing $BaCl_2$ and NaCl. Archibald has completed his observations (referred to last year) on the conductivity of solutions containing NaCl and K_2SO_4 (and therefore also KCl and Na_2SO_4); and they show that the conductivity is similarly calculable up to a total concentration of about 0·5. Archibald has also shown that if the variation, with concentration, of the surface tension and specific gravity of simple solutions of K_2SO_4 and Na_2SO_4 be known, the s. t. and sp. gr. of mixtures up to concentrations of about 1 and 0·5 respectively can be calculated, the method employed being that of my paper in the 'Phil. Mag.,' vol. 44; and that with similar data as to the sp. gr. of NaCl, KCl, Na_2SO_4, and K_2SO_4 solutions, the sp. gr. of solutions containing all these salts up to a concentration of about 0·3 is calculable. It should be noted also that calculations made, by the aid of these coefficients, on the assumption that no double salt exists in solution, of the conductivity and sp. gravity of mixtures of K_2SO_4 and $CuSO_4$ solutions (Archibald), and of the conductivity of mixtures of K_2SO_4 and $MgSO_4$ solutions (McKay) have been found not to agree with observation, except at much lower concentrations than the above, a fact which is probably connected with the formation of double salts by these substances. The limit of experimental error in the above observations was about 0·25, 0·1, and 0·005 per cent. for conductivity, surface tension, and sp. gravity respectively. For accounts of the experiments see current volumes of 'Trans. Roy. Soc. Can. and Trans., N.S. Inst. Sci.'

Schrader, in his 'Elektrolyse von Gemischen' (Berlin, 1897), has tried to determine the ionisation coefficients in mixtures of electrolytes with a common ion by means of electrolytic measurements, using expressions for the coefficients in terms of the conductivity of the mixture, the amounts of the distinctive ions transferred by the current and the Hittorf's transference numbers for these ions. He requires, however, to make a necessarily doubtful assumption as to the relation between the transference numbers in the mixtures and in simple solutions; and some of the quantities involved in his expression for the coefficients are incapable of exact measurement. We cannot, of course, test his values by calculating the conductivity of his mixtures. But if N_1, N_2 are their concentrations with respect to the two electrolytes, and V_1, V_2 the dilutions of their isohydric constituents, his coefficients (a_1, a_2) should satisfy the equations: $a_1/V_1 = a_2/V_2$, and $N_1V_1 + N_2V_2 = 1$ (see last year's paper). Inserting his values of the a's and N's, we may then find the V's and the corresponding a/V's. The a/V's corresponding to the V's thus found may also be obtained with great accuracy from Kohlrausch's and Archibald's observations of conductivity on the assumption that no double molecules are formed in solution, and that both the H's of H_2SO_4 act as cations. When Schrader's results are thus tested, his a/V's are found to be in error in the case of solutions containing KI and KCl by from 1 to 10 per cent., and in the case of solutions containing H_2SO_4 and $CuSO_4$ by from 3·6 to 60 per cent. In the former case the discrepancy is not greater than might be expected from the defects of the method. In the latter it is; and this result is interesting, as it is difficult to account for so great a discrepancy except by the assumption of the existence of molecules of the acid sulphate in solution.

7. *The Carbon-Consuming Cell of Jacques.* *By* S. SKINNER.

The cell consists of an iron vessel containing fused caustic soda in which a carbon rod is placed, the carbon forming the positive element when the cell is sufficiently hot. At lower temperatures the iron is positive. The cell polarises rapidly, and, following the method of Jacques, the polarisation may be removed by blowing air into the fused soda. In the experiments here described, in the place of forcing in air, sodium peroxide is added to the fused soda. The electrolyte then consists of caustic soda, sodium ferrate, and sodium peroxide. This form of cell shows little polarisation. To show that the oxidising substance depolarises at the surface of the iron, experiments were made in a crucible nearly divided into two parts by an iron plate reaching almost to the bottom of the vessel. The carbon was placed in the liquid caustic soda on one side, and the sodium peroxide added to that on the other. It was found that there was an immediate increase in electromotive force on adding the peroxide, thus demonstrating that the depolarising action of the oxidiser was at the iron surface. Another experiment was made in an iron U-tube, the U being loosely plugged with iron wire. The carbon rod was immersed in the soda on one side, and the peroxide was added in the other limb. The same effect was observed.

Experiments were also made to find the rate of consumption of the carbon, and hence to deduce the electro-chemical equivalent. These measurements were complicated by the disintegration of the carbon in the molten liquid even when no current was passing. It is hoped by using more dense and pure carbon to prevent local action and disintegration, and therefore to obtain an experimental value for the electro-chemical equivalent of carbon.

TUESDAY, SEPTEMBER 13.

A discussion was held in conjunction with the International Magnetic Conference and Section G on the Magnetic and Electrolytic Actions of Electric Railways.

Communications were made by Dr. C. Schott, Professor A. W. Rücker, Sec. R.S., Dr. Eschenhagen, Dr. von Bezold, Mr. W. H. Preece, F.R.S., Signor Luigi Palazzo, and Professor A. J. Fleming, F.R.S. See p. 758.

The following Report and Papers were read:—

1. *Report on Electric Standards.*

See Reports, p. 145.

2. *On Standard High Resistances. By* F. B. Fawcett.

The author finds that the electrical resistance of metallic films deposited on glass in high vacua may be rendered constant by prolonged heating in oil under reduced pressure. Resistances of a megohm and upwards have thus been constructed which have not varied more than 0·001 per cent. in the four months since they were finished. The most suitable alloy seems to be one of gold and platinum, and for this the temperature coefficient is about 0·01 per cent. per degree Centigrade. The coefficient is, however, somewhat dependent on the thickness of the film, being less for thin films than for thick ones.

3. *On the Electric Conductivity and Magnetic Permeability of a Series of New Alloys of Iron. By* Professor W. F. Barrett, W. Brown, *and* R. A. Hadfield.

WEDNESDAY, SEPTEMBER 14.

The following Papers were read:—

1. *The Drop of Potential at the Carbons of the Electric Arc.*
By Mrs. Ayrton.

The carbons employed were of the same kind as those used for all my previous experiments on the arc, namely, solid 'Apostle' carbons, the positive 11 mm. and the negative 9 mm. in diameter. In order to eliminate errors caused by the difference in hardness or construction of the carbons, only those were used with which it was found that the P.D. between the carbons was within half a volt of that given by the equation which I published in 1895 connecting that P.D. with the length of the arc and the current flowing.

To find the fall of potential between each of the carbons and the arc a third carbon was used, varying in diameter between 0·5 mm. and 2 mm. This was brought up to the crater of the positive or the white-hot spot on the negative carbon, and the P.D. between it and the main carbon was observed *just before* it touched the main carbon. The P.D. was measured by means of a high-resistance d'Arsonval galvanometer having a resistance of a million and a half ohms in circuit.

Experiments were made with arcs of 1, 2, 3, 4, 5, 6, and 7 mm., and with currents of 4, 5, 6, 7, 8, 9, 10, 12, and 14 amperes.

The drop of potential at the *positive* carbon, I find, is affected both by the length of the arc and the value of the current, and the connection between this P.D. in volts, the current in ampères, and the length of the arc in millimetres may be expressed by the equation:—

$$V = 31{\cdot}28 + \frac{9 + 3{\cdot}1l}{A}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The drop of potential between the arc and the *negative* carbon, on the other hand, is, I find, affected by the *current* only, and *not* by the length of the arc. The equation expressing its connection with the current is—

$$V = 7{\cdot}6 + \frac{13{\cdot}6}{A}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Thus this drop of potential at the *negative* carbon is by no means insignificant, nor have I ever found its sign to change, either with silent or with hissing arcs, as it is said to do by some observers. In all my experiments this drop of potential has been from arc to carbon, and its value has been about one-fourth of the value of the corresponding fall of potential at the positive carbon.

From equations (1) and (2) we can find the equation for the drop of potential at the positive carbon plus the drop of potential at the negative carbon; *i.e.*, the whole fall of potential from carbon to carbon minus the fall of potential through the arc itself. It is

$$V = 38{\cdot}88 + \frac{22{\cdot}6 + 3{\cdot}1l}{A}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Now, the equation I found three years ago for the *total* P.D. between the main carbons, which included, of course, the drop of P.D. in the arc itself, was

$$V = 38{\cdot}88 + 2{\cdot}07l + \frac{11{\cdot}66 + 10{\cdot}54l}{A}. \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The coincidence between the first terms of equations (3) and (4) shows that this constant quantity has at last been tracked home, and that it belongs *not* to the positive carbon alone, as has hitherto been supposed, but to *both* the positive and negative carbons in the proportions of about four-fifths to the former and one-fifth to the latter.

It must be remembered that the experiments upon which equation (3) is based were made nearly two years after those from which equation (4) was obtained, and that for the new equation (3) itself the experiments consisted of two entirely separate sets; the one made to find the drop of potential at the positive carbon and the other to find the drop of potential at the negative carbon.

As regards the accuracy with which equations (1), (2), and (3) express the results of the experiments, it may be mentioned that each of the 124 values from which these equations for the fall of potential at the carbons alone were formed was the mean of the results of from 6 to 12 experiments. Of these 124 values 96 differed by less than 1 volt from the numbers calculated from the equations, 25 differed by between 1 and 2 volts, and only 3 differed by more than 2 volts, and these three all belonged to equation (1).

This closeness of agreement between the observed and calculated values is the result of no series of ingenious guesses, but of the algebraical expression of three very simple straight line laws which, I find, exist between the power expended at each of the carbons, the current flowing, and the length of the arc. These three laws may be most simply expressed thus:—

If W be the power in watts expended at either of the carbons (measured by multiplying the current by the fall of potential at the carbon) and a, b, c, d, e, and f be constants, then

$$\text{For the positive carbon} \begin{cases} W = a + bA \text{ with a constant length of arc,} \\ W = c + dl \quad \text{,,} \qquad \text{,,} \qquad \text{current.} \end{cases}$$

$$\text{For the negative carbon} \quad W = e + fA.$$

A combination of the first two laws gives equation (1), and the third gives equation (2).

The method employed for finding the above falls of potential at each of the carbons was not original. It was first used by Lecher ten years ago, and has since been employed by Uppenborn, by Professor Silvanus Thompson, and by many others. These, however, all used a third carbon placed in a stationary position in the arc, while I considered that more accurate results could be obtained by bringing the point of the third carbon up to touch the hottest part of the main carbon, and observing the last P.D. registered by the voltmeter before it fell to zero. Very accurate and definite results were obtained in this way compared with any I could get by the ordinary method, but in interpreting these results it is necessary to take into account the disadvantages under which *all* experiments made with a bare carbon dipping into the arc labour.

1. The third carbon may not take up the exact potential of the part of the arc in which it is placed.

2. If it does, it will bring all the parts of the arc that it touches to practically one potential, which will be greater than the least, and less than the greatest of the potentials that existed in that portion of the arc before it was occupied by the exploring carbon.

3. It repels the arc, and, therefore, makes its real length greater than its apparent length. Hence the insertion of the exploring carbon usually increases the P.D. between the main carbons by from a half to two volts.

As regards the first disadvantage, it is, of course, possible that there is a contact P.D. between the carbon vapour and the solid exploring carbon, but, even if it exists, this P.D. is probably small compared with the P.D.'s with which we are dealing, and I have, therefore, neglected it in the calculation of the equations.

The second point appears to be much more important, for it is quite possible that the variable part of the fall of potential at each of the carbons, given by equations (1) and (2), may be mainly produced by the exploring carbon being in communication with the arc, not only at its tip, but also along a part of its length. For whether the fall of potential at the carbon itself be a constant or not, it is quite certain that the potentials of the other points at which the arc touched the exploring carbon varied both with the current that was flowing and with the length of the arc before that carbon was inserted. Hence a portion of the variation in the values given by equations (1) and (2) must have been created by the use of a bare carbon in the arc, and it is at least *possible* that the whole of those variations were created in the same way.

Many attempts have been made to explore the arc with insulated conductors, notably by Uppenborn, who tried wires embedded in clay, steatite, and glass tubes, and had to abandon them all. I myself have tried asbestos coverings for the carbons, but the asbestos melted and fell in drops like metal. Now that the importance of insulating the exploring carbon is so very apparent, however, it will be worth while making a very great effort to find some insulating material that will stand the heat of the arc, and will yet not have to be so thick as to disturb it unduly. This I hope very shortly to do, and thus to completely solve the question of the constancy of the drop of potential at the carbons of the arc.

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2. *Some Experiments on the Effect of Pressure on the Thermal Conductivities of Rocks. By* Dr. C. H. LEES.

The experiments were made by the 'lamellar' method, the rocks tested being cut in the form of flat circular discs and placed between discs of steel, the temperatures of which were indicated by thermometers placed in holes in them. Two discs of rock between three discs of steel were used in each experiment, the central disc of steel having embedded in it a coil of insulated wire through which an electric current of known amount could be sent. Through the upper and lower steel discs, which were hollow, a flow of water was maintained. Thermal contact between steel and rock discs was improved by a thin layer of glycerine. The results show an increase of conductivity as the pressure is raised from zero to 800 or 900 lbs. per square inch, which is very small in the case of granite and marble, slightly greater in the case of slate, and about 3 per cent. in the case of a rather soft sandstone.

3. *On the Determination of the Thermal Conductivity of Water.*
By S. R. Milner, *B.Sc., and* Professor A. P. Chattock.

This is a description of a modification of the method of Dr. C. H. Lees, in which the same platinum coils are used both for providing the flow of heat and for measuring the resulting temperature gradient. The result obtained by taking the mean of about forty separate determinations is 0·001435 c.g s. units at 20°C.

4. *Experiments on the Influence of Electricity on Plants.*
By Selim Lemström.

A brief sketch is given of previous experiments and theories founded thereon. The author has taken up the subject again for the following reasons:—

(*a*) In previous experiments there was nearly always a favourable result when artificial electricity was used. The extraordinary development of the vegetation in northern regions, in spite of the hard climatic circumstances. Periodicity in the crops of different seeds, which follows closely the periodicity of the sun-spots and the auroras, at least in more northern countries.

(*b*) The same periodicity in the development of the annual rings in the pine-wood.

(*c*) The unexplained physiological functions of the needle-formed leaves of the pine and of the brush on the ears of the seed.

After having found, and as nearly as possible proved, that the auroras are caused by electric currents in the atmosphere, the author began a long series of experiments, using a current of static electricity from points:

1. In the laboratory with various seeds;
2. In Wichtis parish in Finland on a small cornfield;
3. On the field of the Horticultural Society in Helsingfors and on a wheat-field in the Estate Brödtorp.

As all these experiments, performed in 1885 and 1886, had given favourable results, about 40 per cent. increase of the plants treated with electricity, the author made the necessary preparations for more extensive experiments in the year 1897. They were carried out on the Estate Brödtorp, with the friendly assistance of the proprietor, Baron Edvard Hisinger.

Three fields of 50 m. were used for the experiments, and three of the same area as control-fields.

The results were the following:—

There has been in general an increase in the seeds of at least 40 per cent.; in the roots from 25 per cent. to 75 per cent., depending on the kind of plant and on the nature of the soil; beans, 75 per cent.; strawberries and raspberries as high as 75 per cent., and the time for their ripening shortened at least one-third.

From these experiments it follows:—

1. The more fertile the soil the greater the increase;
2. Some plants were improved by electricity, whilst others, such as carrots, behaved differently.

Later experiments, however, have shown that this peculiarity depended on want of water. It seems that under the influence of electricity the plants absorb water in greater quantity.

In the year 1888 the experiments were made near the Castle Laferté, in Bourgogne, through the kindness of Baron Arnould Thénard.

The results were in general the same as in Finland, though the weather during the summer of 1888 was not favourable.

Among the facts which result from these experiments it is proved that electricity, given to plants during days with a clear burning sun, can damage them very much, if enough water is not also given at the same time.

In what way does electricity exert an influence on plants? Either the gases in the air are transformed to ozone and nitric oxides, which being heavy fall down upon the plants and increase the activity of their vegetation; or the electricity induces the juices of the plants to ascend more rapidly in their capillary tubes (the Gernez phenomenon).

Though there is much not yet explained, the method is ready to be used for practical purposes, especially as the author has succeeded in constructing an electric machine that will be much more applicable for the purpose than the older ones, amongst which the well-known Wimshurst machine has been used with good effect.

For the present occasion the author has this summer carried out some experiments in Finland, at the cottage Kammio near Helsingfors, through the kindness of Dr. W. E. Lybeck, on some especially interesting plants. Of these, the tobacco plant did not yield, in earlier experiments, to the favourable influence of the electric currents, through want of water. Photographs of the experimental and the control field, which were watered to the same extent, have been prepared. The pictures were taken at the same distance from both fields, and show that under the influence of the current the results are at least 40 per cent. better than without it. The current was applied for four hours in the morning and four hours in the afternoon, with many interruptions, however, from June 17 to July 30. The total number of hours was 161.

5. *The Action of Electricity upon Plants.*
By E. H. Cook, *D.Sc. Lond., Clifton Laboratory, Bristol.*

The experiments recorded in this Paper were commenced so far back as 1886. They have been repeated many times as the conditions affecting the results gradually became known. They may be considered under three heads: (1) Those relating to the germination of seeds; (2) those relating to the growing of plants in soil; (3) those dealing with the lower forms of plant life, such as Algæ, Fungi, &c.

The influence of electricity on the germination of seeds showed that the general effect was to give an increased development in the seeds amounting to from 10 to 20 per cent more than in the non-electrified ones.

The influence on growing plants showed that in almost every case the electrically-treated plants came to maturity first, and they were also the first to show above the soil, but I could not satisfy myself that with the currents employed, viz., from 1 to 30 milliamperes, and with an E.M.F. of from 5 to 25 volts, any increased rate of growth was observable after the cotyledons appeared above the soil.

In order to compare the effects of the battery, the induction coil, and the machine, experiments were made with the same seeds grown, (1) without any electricity, (2) with a current passing between carbon electrodes, (3) under the positive point from a Wimshurst machine, (4) under the negative from the same, (5) under the positive point of an induction coil, and (6) under the negative point of an induction coil. In every case the positive end of the coil produced the greatest effect. This was with an E.M.F. of approximately 45,000 volts.

Experiments have been made with yeast, spirogyra, and other large-celled fresh-water Algæ. It is intended to continue these experiments.

Applications on the Large Scale.—Experiments have been made by M. Barratt and M. Spechnew by connecting large plates of copper and zinc sunk in the soil with a wire and growing plants between them, and also by connecting plates to a battery. It is, however, evident that if atmospheric electricity could be employed, a practically unlimited source is available. Beckeinstener was the first to try this. Following him, several experimenters in France and other countries have invented, perfected, and used what has been called the 'Geomagnetifère' with remarkable results. The instrument is practically a lightning-conductor set up in the middle of a field, and connected below with a series of cross wires running under the soil near the roots of the plants. The results obtained with this instrument, as given in the French journals, were so remarkable, that I was very desirous of making a trial in Clifton. Accordingly, in the early spring, M. Pinot de Moira, who is an excellent amateur gardener as well as a careful experimenter, put up one in his garden on Clifton Hill. Potatoes, beans, peas, &c., were grown near the wires and in other parts of the garden. An increased effect was distinctly observed in all cases, thus confirming in some measure the results of the French experimenters. It is, however, much to be desired that further and continuous experiments should be carried out.

The theories to account for the action were then considered.

6. *Experiments with the Brush Discharge.*
By E. H. COOK, *D.Sc. Lond., Clifton Laboratory, Bristol.*

7. *The Ancient Standard Weights and Measures of the City of Bristol.* *By* W. R. BARKER.

This group of Standard Weights and Measures forms an interesting link with the past history of the city at various stages. The apparent rarity of local standards of this kind was referred to and accounted for. Three periods were recognised in which wholesale reforms were introduced by the issue of fresh standards—Henry VII., Elizabeth, George IV. (Imperial System). Each of these three issues is represented by one or more specimens in the collection. As circumstances required, or sovereigns succeeded to the throne, intermediate standards were issued, or the old ones were adopted under the new reign, so that, in addition to those mentioned above, there are in this collection other standards authorised under six other sovereigns, the whole embracing the long period from 1495 to 1824. In all there are eighteen measures of capacity, two standard yard measures, and thirteen weights. The marks, dates, and other peculiarities of each were considered chronologically.

8. *Some Preliminary Experiments on the Luminosity produced by striking Sugar.* *By* J. BURKE, *M.A.*

The experiments show that the appearance of the flash produced when two lumps of sugar are struck is independent of the gas in which the impact occurs; for instance, the effect is the same both in colour and intensity whether the spark, if we might so call it, takes place in air or coal gas, and moreover is independent of the pressure of the gas. The experiments have also been tried in water with similar results. The spectrum of the flash is continuous, and confined to the more refrangible end of the visible spectrum; which seems to show that the luminosity cannot be due to the particles of sugar on the impinged surface becoming white hot; but that the effect is probably due to some change in the configuration of the crystals. The fact that the surrounding medium in which the spark occurs does not alter the luminosity either in colour or intensity, seems to show that chemical action with the surrounding medium does not take part in the production of the light. An almost continuous luminosity can be produced by striking rapidly the circumference of a rotating wheel of sugar. The effect is very much greater when the wheel is struck while it is rotating than when it is at rest; but the mere rubbing of the surface, whilst rotating, does not give rise to a very marked effect. The sugar wears out very rapidly, and in order to keep the image of the spark on the slit of the spectroscope the whole apparatus is moved slowly at the rate of about 2 inches an hour, by which means the luminosity always takes place along the axis of the collimator.

9. *On the Electromagnetic Theory of Reflection on the Surface of Crystals.* *By* Dr. CHAS. E. CURRY.

When ordinary light strikes the surface of an isotropic insulator, as glass, at such an angle that the reflected and the refracted rays form a right angle with each other, the reflected ray is found to be linearly polarised (Brewster's law). To my knowledge, however, little is known about the light reflected from the surface of crystals.

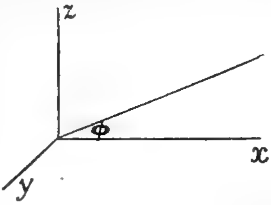
In the treatment of the behaviour of light on the surface of crystals it is customary to make use of the so-called 'uniradial azimuths' introduced by MacCullagh; their determination depends on the properties of the given crystal (the reflecting surface used, &c.), and the angle of incidence of the given wave, but not on the azimuth, in which the given oscillation is taking place. These uniradial azimuths are, as we know, rotated through certain angles upon reflection. Are there now angles of incidence ϕ, for which the uniradial azimuths coincide with each other after reflection? The general condition for such a coincidence is [1]

$$\frac{\sin\theta_o \sin(\phi-\phi_o)}{\cos\theta_o \sin(\phi-\phi_o)\cos(\phi+\phi_o) - \tan\epsilon_o \sin^2\phi_o}$$
$$= \frac{\sin v_e \sin(\phi-\phi_e)}{\cos\theta_e \sin(\phi-\phi_e)\cos(\phi+\phi_e) - \tan\epsilon_e \sin^2\phi_e}, \quad (1)$$

where o refers to the ordinary and e to the extraordinary wave; ϕ_o and ϕ_e denote here the angles of refraction of the ordinary and extraordinary wave respectively, θ_o and θ_e their respective azimuths, and ϵ_o and ϵ_e the small angles between the directions of propagation of these waves and those of their so-called rays.

This condition (1) may be regarded as an equation for the determination of the angle ϕ; we observe that it does not contain the azimuth θ of the incident wave. It thus follows: when ordinary light strikes the surface of the given crystal at such an angle ϕ, determined by this equation, it will be reflected as linearly polarised, as in the case of an isotropic insulator, or certain phenomena as those of interference will make their appearance; which of these phenomena occur will, however, depend upon the assumption made with regard to the behaviour of the ether-molecules in the film between the two bodies. Conversely, observations of such phenomena might throw light on the assumption to be made.

The above equation for ϕ is, however, too general to admit of a solution; all information must thus be gained from an examination of special cases; I have chosen the following one for the present purpose, since it appears to be of particular interest. Let one of the principal planes of the given crystal be taken as reflecting surface, and let the plane of incidence lie in one of the other two, as indicated in the annexed figure.



($y\,z$ reflecting plane, $x\,y$ incident plane)

The above equation for ϕ then reduces to

$$\sin(\phi-\phi_e)\cos(\phi+\phi_e) - \tan\epsilon_e \sin^2\phi_e = 0; \quad . \quad . \quad . \quad (2)$$

its derivation, into which I cannot enter here, requires considerable care, chiefly on account of the appearance of indeterminate forms.

Explicitly, it can be written

$$v^2[v^2-(A^2-B^2)\sin^2\phi]\cos\phi = B\sqrt{v^2-A^2\sin^2\phi}\,[v^2+(A^2-B^2)\sin^2\phi], \quad . \quad (3)$$

where *A*, *B*, *C* are three medium constants of the dimensions of a velocity, and v the velocity of propagation of electromagnetic disturbances in air.

For isotropic insulators, i.e. $A=B=C$, this equation for ϕ becomes

$$\sin^2\phi = \frac{v^2}{v^2+A^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

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[1] Cf. also P. Volkmann, *Vorlesungen über die Theorie des Lichtes*, p. 341.

which is identical to the condition that

$$\phi + \phi_e = \frac{\pi}{2};$$

or, in more familiar form, that the reflected and the refracted rays form a right angle with each other. It is evident from the above simple relation that, if v and ϕ can be determined by experiment, A will be given.

Even a general examination of the above special equation (3) would be too long here; I shall, therefore, confine myself to the particular case where A, B, and C are assigned given numerical values; for sulphur Boltzmann[1] has found the following values for the constants of electric induction:

$$4{\cdot}773 \qquad 3{\cdot}970 \qquad 3{\cdot}811.$$

For these values the above equation (3) reduces approximately to

$$\sin{}^6\phi + 51{\cdot}7 \sin{}^4\phi + 494{\cdot}8 \sin{}^2\phi - 440 = 0,$$

one root of which is

$$\phi = 64^\circ\ 44';$$

the other roots are imaginary.

Similarly, we find another angle of polarisation ϕ on interchanging the above x (A) and y (B) co-ordinate axes with each other. The general equation in ϕ must then evidently be written

$$v^2\,[v^2 + (\mathrm{A}^2 - \mathrm{B}^2) \sin{}^2\phi] \cos\phi = \mathrm{A}\sqrt{v^2 = \mathrm{B}^2 \sin{}^2\phi}\;[v^2 - (\mathrm{A}^2 - \mathrm{B}^2) \sin{}^2\phi].$$

This equation reduces for the given particular case to

$$\sin{}^6\phi - 53.35 \sin{}^4\phi + 617.53 \sin{}^2\phi - 465 = 0;$$

one root of which is

$$\phi = 64^\circ\ 7'\ 30'';$$

the other roots are imaginary.

If now we are able to determine by experiment two such critical values of ϕ, characterised by linearly polarised light or other phenomena, we should then have two equations for the determination of the quantities A and B. Although the actual solution of these equations with regard to A and B offers difficulty, very approximate ones can always be found.

Similarly, to determine the third medium-constant C, we have only to choose those principal planes of the given crystals as reflecting and incident planes, for which the above formula (2) reduces to a function of C and A or B only.

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[1] Cf. *Pogg. Ann.* 153, 1874. 'Experimentaluntersuchung über das Verhalten nicht leitender Körper unter dem Einflusse elektrischer Kräfte.' Also Poincaré's *Electricité et optique*, vol. i. p. 129.

Section B.—CHEMISTRY.

President of the Section.—Professor F. R. Japp, M.A., LL.D., F.R.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

Stereochemistry and Vitalism.

Of the numerous weighty discoveries which science owes to the genius of Pasteur, none appeals more strongly to chemists than that with which he opened his career as an investigator—the establishing of the connection between optical activity and molecular asymmetry in organic compounds. The extraordinary subtlety of the modes of isomerism then for the first time disclosed; the novelty and refinement of the means employed in the separation of the isomerides; the felicitous geometrical hypothesis adopted to account for the facts—an hypothesis which subsequent investigation has served but to confirm; the perfect balance of inductive and deductive method; and lastly, the circumstance that in these researches Pasteur laid the foundation of the science of stereochemistry: these are characteristics any one of which would have sufficed to render the work eminently noteworthy, but which, taken together, stamp it as the capital achievement of organic chemistry.

Physiologists, on the other hand, are naturally more attracted by Pasteur's subsequent work, in which the biological element predominates; in fact, I doubt whether many of them have given much attention to the earlier work. And yet it ought to be of interest to physiologists, not merely because it is the root from which the later work springs, but because it furnishes, I am convinced, a reply to the most fundamental question that physiology can propose to itself—namely, whether the phenomena of life are wholly explicable in terms of chemistry and physics; in other words, whether they are reducible to problems of the kinetics of atoms, or whether, on the contrary, there are certain residual phenomena, inexplicable by such means, pointing to the existence of a directive force which enters upon the scene with life itself, and which, whilst in no way violating the laws of the kinetics of atoms—whilst, indeed, acting through these laws—determines the course of their operation within the living organism.

The latter view is known as Vitalism. At one time universally held, although in a cruder form than that just stated, it fell, later on, into disrepute; 'vital force,' the hypothetical and undefined cause of the special phenomena of life, was relegated to the category of occult qualities; and the problems of physiology were declared to be solely problems of chemistry and physics. Various causes contributed to this result. In the first place, the mere name 'vital force' explains nothing; although, of course, one may make this admission without thereby conceding that chemistry and physics explain everything. Secondly, the older vitalists confounded force with energy; their 'vital force' was a source of energy;

so that their doctrines contradicted the law of the conservation of energy, and became untenable the moment that this law was established. I would point out, however, that the assumption of a purely directive 'vital force,' such as I have just referred to, using the word 'force' in the sense which it bears in modern dynamics, does not *necessarily* involve this contradiction ; for a force acting on a moving body at right angles to its path does no work, although it may continuously alter the direction in which the body moves. When, therefore, Professor J. Burdon Sanderson writes: 'The proof of the non-existence of a special "vital force" lies in the demonstration of the adequacy of the known sources of energy in the organism to account for the actual day by day expenditure of heat and work,' he does not consider this special case. The application of the foregoing principle of dynamics to the discussion of problems like the present is, I believe, due to the late Professor Fleeming Jenkin. A third ground for abandoning the doctrine of a 'vital force' was the discovery that numerous organic compounds for the production of which the living organism was supposed to be necessary could be synthesised by laboratory methods from inorganic materials. It is the validity of some of the conclusions drawn from the latter fact that I wish especially to consider.

Recent years have, however, witnessed a significant revival of the doctrine of vitalism among the physiologists of the younger generation.

It is not my intention to offer any opinion on the various arguments which physiologists of the neo-vitalistic school have put forward in support of their views; these arguments and the facts on which they are based lie entirely outside my province. I shall confine myself to a single class of chemical facts rendered accessible by Pasteur's researches on optically active compounds, and, considering these facts in the light of our present views regarding the constitution of organic compounds, I shall endeavour to show that living matter is constantly performing a certain geometrical feat which dead matter, unless indeed it happens to belong to a particular class of products of the living organism and to be thus ultimately referable to living matter, is incapable—not even conceivably capable—of performing. My argument, being based on geometrical and dynamical considerations, will have the advantage, over the physiological arguments, of immeasurably greater simplicity; so that, at all events, any fallacy into which I may unwittingly fall will be the more readily detected.

In order to make clear the bearing of the results of stereochemical research on this physiological problem, it will be necessary to give a brief sketch of the stereochemistry of optically active organic compounds, as founded by Pasteur and as further developed by later investigators.

Substances are said to be optically active when they produce rotation of the plane of polarisation of a ray of polarised light which passes through them. The rotation may be either to the right or to the left, according to the nature of the substance; in the former case the substance in said to be dextro-rotatory; in the latter, lævo-rotatory. The effect is as if the ray had been forced through a twisted medium—a medium with a right-handed or a left-handed twist—and had itself received a twist in the process; and the amount of the rotation will depend upon the degree of 'twist' in the medium (that is, on the rotatory power of substance) and upon the thickness of the stratum of substance through which the ray passes, just as the angle through which a bullet turns in passing from the breech to the muzzle of a rifle will depend upon the degree of twist in the rifling and the length of the barrel. If the bullet had passed through the barrel in the opposite direction, the rotation would still have been in the same sense; since a right-handed (or left-handed) twist or helix remains the same from whichever end it is viewed, in whichever direction it is traversed. This also applies to optically active substances; if the polarised ray passes through the substance in the opposite direction, the rotation still occurs in the same sense as before. This characteristic sharply distinguishes the rotation due to optically active substances from that produced by the magnetic field, the latter rotation being reversed on reversing the direction of the polarised ray.

Optically active substances may be divided into two classes. Some, like quartz, sodium chlorate, and benzil, produce rotation only when in the crystallised state; the dissolved (or fused) substances are inactive. Others, like oil of turpentine, camphor, and sugar, are optically active when in the liquid state or in solution. In the former case the molecules of the substance have no twisted structure, but they unite to form crystals having such a structure. As Pasteur expressed it, we may build up a spiral staircase—an asymmetric figure—from symmetric bricks; when the staircase is again resolved into its component bricks, the asymmetry disappears. (I will explain presently the precise significance of the terms symmetry and asymmetry as used in this connection.) In the case of compounds which are optically active in the liquid state, the twisted structure must be predicated of the molecules themselves; that is, there must be a twisted arrangement of the atoms which form these molecules.

The earliest known experimental facts regarding the rotation of the plane of polarisation by various substances, solid and liquid, were discovered by Arago and by Biot.

After this preliminary statement as to what is understood by optical activity, we may consider Pasteur's special contributions to the solution of the problems involved.

Pasteur tells us, in the well-known 'Lectures on the Molecular Asymmetry of Natural Organic Products,' which he delivered in 1860, before the Chemical Society of Paris, that his earliest independent scientific work dealt with the subject of crystallography, to which he had turned his attention from a conviction that it would prove useful to him in the study of chemistry. In order to perfect himself in crystallographical methods, he resolved to repeat all the measurements contained in a memoir by De la Provostaye on the crystalline forms of tartaric acid, racemic acid, and their salts. These two sets of compounds have the same composition, except that they frequently differ in the number of molecules of water of crystallisation which they contain; but whereas tartaric acid and the tartrates are dextro-rotatory, racemic acid and the racemates are optically inactive. It was probably this circumstance that decided Pasteur in his choice of a subject, for it appears that, even as a student, he had been attracted by the problem of optical activity. In the course of the repetition, however, he detected a fact which had escaped the notice of his predecessor in the work, accurate observer as the latter was—namely, the presence, in the tartrates, of right-handed hemihedral faces, which are absent in the racemates. Hemihedral faces are such as occur in only half their possible number; and in the case of non-superposable hemihedry, to which class that of the tartrates belongs, there are always two opposite hemihedral forms possible: a right-handed or dextro-form, and a left-handed or lævo-form. Which is right, and which is left, is a matter of convention; but they are opposite forms, and differ from one another exactly as the right hand of the human body differs from the left: that is, they resemble one another in every respect, except that they are non-superposable—the one cannot be made to coincide in space with the other, just as a right hand will not fit into a left-hand glove. The one form is identical with the mirror image of the other: thus the mirror image of a right hand is a left hand. Such opposite hemihedral crystalline forms are termed *enantiomorphs*; they have the same faces and the same angles, but differ in the fact that all positions in the one are reversed in the other for one dimension of space, and left unchanged for the other two dimensions; this being the geometrical transformation which an object appears to undergo when reflected in a plane mirror. Enantiomorphism is possible only in the case of asymmetric solid figures: these alone give non-superposable mirror images. Any object which gives a mirror image identical with the object itself—a superposable mirror image—must have at least one plane of symmetry.

The hemihedry of the tartrates discovered by Pasteur is in every case in the same sense—that termed right-handed—provided that the crystals are oriented according to two of the axes which have nearly the same ratio in all the tartrates.

Pasteur was inclined to connect the molecular dextro-rotatory power of the tartrates with this right-handed hemihedry; since in the racemates both the hemihedry and the rotatory power were absent. A similar connection, which, however, held good only for the crystalline condition, had, as he points out, been already observed in the case of quartz, the crystals of which occasionally exhibit small asymmetric (tetartohedral) faces, situated in some specimens to the right and in others to the left; the former specimens being dextro-, the latter, lævo-rotatory. The possibility of this connection was first suggested by Sir John Herschel.

Pasteur's views were confirmed by an unexpected discovery which he made shortly after. Mitscherlich had stated, in 1844, in a communication to Biot, which the latter laid before the French Academy of Sciences, that sodium ammonium tartrate and sodium ammonium racemate were identical, not merely in chemical composition, but in crystalline form, in specific gravity, and in every other property, chemical and physical, except that the solution of the former salt was dextro-rotatory, that of the latter inactive. And to make his statement still more definite, he added: 'The nature and the number of the atoms, their arrangement, and their distances from one another, are the same in both compounds.'

At the time this passage appeared Pasteur was a student in the École Normale. He tells us how it puzzled him, as being in contradiction to the views universally held by physicists and chemists, that the properties, chemical and physical, of substances depended on the nature, number, and arrangement of their constituent atoms. He now returned to the subject, imagining that the explanation would be found in the fact that Mitscherlich had overlooked the hemihedral faces in the tartrate, and that the racemate would not be hemihedral. He therefore prepared and examined the two double salts. He found that the tartrate was, like all the other tartrates which he had investigated, hemihedral; but, to his surprise, the solution of the racemate also deposited hemihedral crystals. A closer examination, however, disclosed the fact that, whereas in the tartrate all the hemihedral faces were situated to the right, in the crystals from the solution of the racemate they were situated sometimes to the right, and sometimes to the left. Mindful of his view regarding the connection between the sense of the hemihedry and that of the optical activity, he carefully picked out and separated the dextro- and lævo-hemihedral crystals, made a solution of each kind separately, and observed it in the polarimeter. To his surprise and delight, the solution of the right-handed crystals was dextro-rotatory; that of the left-handed, lævo-rotatory. The right-handed crystals were identical with those of the ordinary (dextro-) tartrate; the others, which were their mirror image, or enantiomorph, were derived from the hitherto unknown lævo-tartaric acid. From the dextro- and lævo-salts thus separated he prepared the free dextro- and lævo-tartaric acids. And having thus obtained from racemic acid its two component acids—dextro- and lævo-tartaric acids—it was an easy matter to recompose racemic acid. He found that, on mixing equal weights of the two opposite acids, each previously dissolved in a little water, the solution almost solidified, depositing a mass of crystals of racemic acid.

These two tartaric acids have the same properties, chemical and physical, except where their opposite asymmetry comes into play. They crystallise in the same forms, with the same faces and angles; but the hemihedral facets, which in the one are situated to the right, are, in the other, situated to the left. Their specific gravities and solubilities are the same; but the solution of the one is dextro-rotatory; of the other, lævo-rotatory. The salts which they form with inorganic bases also agree in every respect, except as regards their opposite asymmetry and opposite rotatory power. They are enantiomorphous.

Pasteur, discussing the question of the molecular constitution of these acids, anticipates in a remarkable manner the views at present held by chemists. 'We know, on the one hand,' he says, 'that the molecular structures of the two tartaric acids are asymmetric, and on the other, that they are rigorously the same, with the sole difference of showing asymmetry in opposite senses. Are the atoms of the right acid grouped on the spirals of a right-handed helix, or placed at the solid angles of an irregular tetrahedron, or disposed according to some particular asymmetric grouping or other? We cannot answer these questions. But it cannot be a subject of doubt that there exists an arrangement of the atoms in an asymmetric order having a non-superposable image. It is not less certain that the atoms of the left acid realise precisely the asymmetric grouping which is the inverse of this.'

The idea of the irregular tetrahedron is, it may be explained, derived from the hemihedral facets. Imagine these to develop in the case of dextro-tartaric acid until the other faces of the crystal disappear, and there results an irregular tetrahedron. Repeat the process with a crystal of lævo-tartaric acid, and the enantiomorphous tetrahedron—the mirror-image of the former—is obtained. We shall see later that the idea, on the one hand, of two asymmetric tetrahedra, and, on the other, that of two opposite helices, given as alternatives by Pasteur to explain the grouping of the atoms within the molecules of dextro- and lævo-tartaric acids, are in reality identical.

The precision of Pasteur's views as to the asymmetry of these acids enabled him to discover two further methods of separating them. Thus he points out that although these acids will possess equal affinity for any given symmetric base, such as potash, or ammonia, or aniline, yet their affinities will not be equal if the base, like quinine or strychnine, is itself asymmetric; because here the special one-sided asymmetry of the base will modify its mode of combination with the two enantiomorphous acids. The solubility is different in the case of the dextro- and lævo-tartrates of the same asymmetric base; the crystalline form, the specific gravity, the number of molecules of water of crystallisation, may be all different. Potassium dextro- and lævo-tartrates are mirror images of one another; quinine dextro- and lævo-tartrates are not. Pasteur employed in his experiments the asymmetric base cinchonicine, which he converted into its acid racemate, and allowed the solution to crystallise. The first crystallisations consisted of pure lævo-tartrate of cinchonicine, whilst the more soluble dextro-tartrate remained in the mother liquor, from which it finally crystallised in forms totally distinct from those of the lævo-tartrate.

Pasteur's third method is of physiological interest, and is, moreover, the stepping-stone to his later work on ferments. As we shall see presently, he regarded the formation of asymmetric organic compounds as the special prerogative of the living organism. Most of the substances of which the animal and vegetable tissues are built up—the proteids, cellulose—are asymmetric organic compounds, displaying optical activity. Pasteur had shown that two compounds of inverse asymmetry behaved differently towards a third asymmetric compound. How would they behave towards the asymmetric living organism?

It had frequently been noticed that impure calcium tartrate, when mixed with organic matters, as is the case when it is obtained in the process of preparing tartaric acid from argol, readily underwent fermentation. Pasteur examined the action of the ferment (apparently a *Penicillium*) on ammonium tartrate—a substance which had the advantage over calcium tartrate of being soluble—and, finding that the fermentation here followed a normal course, ending with the destruction of the tartrate, repeated the experiment with ammonium racemate, examining the solution from time to time with the polarimeter. The fermentation proceeded, apparently, as before; but the solution, originally optically inactive, became lævorotatory, the activity gradually increasing in amount until a maximum was reached. At this point the fermentation ceased. The whole of the dextro-tartrate had disappeared, and from the solution the lævo-tartrate was obtained in a state of purity. The asymmetric living organism had selected for its nutriment that particular asymmetric form of tartaric acid which suited its needs—the form, doubtless, which in some way fitted its own asymmetry—and had left the opposite form either wholly or, for the most part, untouched. The asymmetric micro-organism, therefore, exhibits a power which no symmetric chemical substance, such as our ordinary oxidising agents, and no symmetric form of energy, such as heat, can ever possess: it distinguishes between enantiomorphs. If we oxidise racemic acid with nitric acid, for example, both the enantiomorphous constituents are attacked in exactly the same degree. If we heat racemic acid, whatever happens to its right-handed constituent happens equally to its left-handed constituent: the temperature of decomposition of both is the same. Asymmetric agents can alone display selective action in dealing with enantiomorphs.

By the action of heat Pasteur converted ordinary tartaric acid into racemic acid, in which process a portion of the right acid is converted into the left, an equilibrium being established; and lævo-tartaric acid may be converted into racemic acid in the same way, the inverse change taking place. At the same time, a new tartaric acid is formed in both cases: mesotartaric acid, or true inactive tartaric acid, which resembles racemic acid in having no action on the plane of polarisation, but differs from it in not being separable into two acids of opposite activity. According to our present views, it contains two equal and opposite asymmetric groups *within* its molecule. Racemic acid is thus inactive by *inter*molecular compensation; mesotartaric acid, by *intra*molecular compensation.

Pasteur, generalising somewhat hastily from the few cases which he had studied, came to the conclusion that all organic compounds capable of exhibiting optical activity might exist in the foregoing four forms—dextro, lævo, racemoid, and meso. As regards the dextro and lævo forms, this is correct; as regards the racemoid form it is generally correct; but the meso form, as we now know, is a very special case, implying that the molecule contains two structurally identical complexes of opposite asymmetry.

Were I following the exact historical order, I should introduce here Pasteur's view that compounds exhibiting optical activity have never been obtained without the intervention of life—a view which it is the object of the present address to consider. The later developments of stereochemistry, however, throw so much light on this question, and enable us to discuss it with such precision, that we shall turn our attention to these first. Before so doing, however, we may note that, in spite of the immense growth in the material of stereochemistry, and in spite of the development of the theoretical views of stereochemists, hardly any experimental method of fundamental importance for the separation and transformation of optically active compounds has been added to those described in Pasteur's classical researches, although it is almost forty years since these came to a close. Perhaps Walden's remarkable discovery of a method for the transformation of certain enantiomorphs into their optical opposites without previous racemisation, is the only one entitled to be so classed.

Pasteur was in advance of his time, and his theory of molecular asymmetry was a seed that lay for many years in the ground without germinating.

In 1858, just about the period when Pasteur was concluding his researches in the foregoing field, Kekulé published his celebrated theoretical paper, 'On the Constitution and Metamorphoses of Chemical Compounds, and on the Chemical Nature of Carbon,' in which he showed that, by assuming that the carbon atom had four units of affinity, the constitution of organic compounds could be satisfactorily explained. This was the starting-point of the theory of chemical structure, and from that time to the present day organic chemists have been engaged, with enormous expenditure of labour, in determining the constitution or molecular structure of the carbon compounds on the lines of Kekulé's theory.

In order that Pasteur's ideas should bear fruit it was only necessary that his purely general statements with regard to molecular asymmetry should be specialised, so as to include the recognised constitution of organic compounds. It was from this union of Pasteur's theory with that of Kekulé that modern stereochemistry sprang. The necessary step was taken, independently and almost simultaneously, by Van't Hoff and Le Bel, in 1874. I will briefly state their conclusions, so far as these bear on the subject of optical activity.

If we examine the structural formulæ of a number of thoroughly investigated optically active organic compounds, we shall find that the molecule of each contains at least one carbon atom of which the four affinities are satisfied by four different atoms or groups—an asymmetric carbon atom, as it is termed.

The four affinities, or directed attractive powers, of the carbon atom are not to be conceived of as lying in one plane. The simplest assumption that we can make with regard to their distribution in space is that the direction of each makes equal angles with the directions of the three others. We may express this differently by saying that the four atoms or groups attached to the carbon atom are situated at the solid angles of a tetrahedron, in the centre of which the carbon atom itself is placed. If the four atoms or groups are all identical they will be equally attracted by the carbon atom; consequently they will be equidistant from it, and the tetrahedron will be regular. If they are all different the force with which each is attracted will be different; they will arrange themselves at different distances from the carbon atom; and the tetrahedron will be irregular: it will have no plane of symmetry. Any compound of the formula $CHX'Y'Z'$ can therefore exist in two enantiomorphs, applying this term to the molecules themselves—in two non-superposable forms, each of which is the mirror image of the other: thus—

FIG. 1.

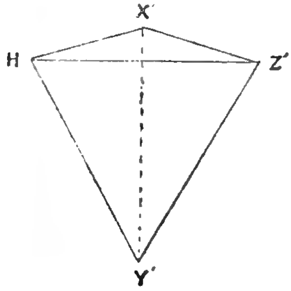
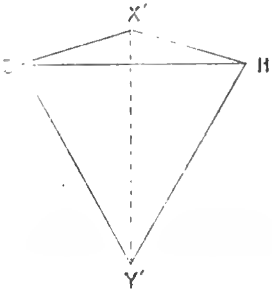


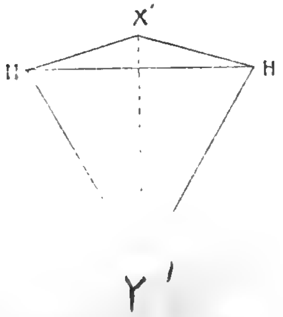
FIG. 2.



(In these figures no attempt has been made to represent the tetrahedra as irregular; the opposite asymmetry is indicated merely by the opposite order of the four attached atoms or groups. In reality, however, they would be irregular. The carbon atom itself is not shown.)

If we consider any particular set of three atoms or groups—for example, H, Z', and Y'—looking towards that face of the tetrahedron about which they are arranged, any order, thus HZ'Y', which is clockwise in one figure, will be counterclockwise in the other. In like manner, a continuous curve, passing through the four atoms or groups in any given sequence, will form a right-handed helix in the one case and a left-handed helix in the other. We thus find that the foregoing assumptions—the very simplest that could be made—regarding the distribution of the four affinities of carbon and the different degree with which four different atoms or groups will be attracted by the carbon atom to which they are attached, lead to the asymmetric structures postulated by Pasteur to account for optical activity—namely, enantiomorphous irregular tetrahedra, and right- and left-handed helices.

FIG. 3.



Y'

That a spiral arrangement, right- or left-handed, will produce rotation of the plane of polarisation in its own sense, may be shown by various experiments: thus in Reusch's optically active piles of plates of mica, produced by crossing successive plates of biaxal mica at an angle of 60° to one another; or in the twisted jute fibres recently described by Professor Bose, which, according to the direction

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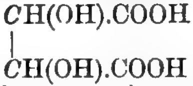
of the twist previously imparted to them, rotate the plane of polarisation of electric waves either to the right or to the left.

If two of the four atoms or groups attached to carbon are identical, there is no asymmetry, and no optical activity. Thus, in a compound of the formula $CH_2X'Y'$, which we may represent by our tetrahedral scheme as shown in fig. 3, the two hydrogen atoms are equidistant from the carbon atom; the system has a plane of symmetry passing through X' Y' and the carbon atom, and has therefore a superposable mirror image.

If the molecule contains only one asymmetric carbon atom, the latter may be either positive or negative, so that the substance may exist in two forms of opposite optical activity; in addition to which we may have the racemoid combination of the two, which will be inactive but separable. Mandelic acid, $C_6H_5.\mathit{C}H(OH).COOH$,[1] is a case in point: it is known in these three forms.

If, as in the case of tartaric acid,  $\begin{array}{l}\mathit{C}H(OH).COOH\\ |\\ \mathit{C}H(OH).COOH\end{array}$, the molecule contains two asymmetric carbon atoms, and at the same time consists of two structurally identical halves, then these two atoms may be either both positive or both negative, reinforcing each other's effect in either case; or one may be positive and the other negative, when, owing to the structural identity of the two halves of the molecule, the effect of the one will exactly compensate that of the other, and the compound will be inactive, but not separable. Furthermore, there may be the racemic combination of the bi-dextro- form with the bi-lævo- form: a combination inactive, but separable. We have thus the explanation of the four forms observed by Pasteur.

In fact, all the complex cases of isomerism that have been met with among compounds of this class—compounds structurally identical, but configuratively distinct, as it is termed—may be satisfactorily explained, and their possible number accurately predicted, by means of the theory of the asymmetric carbon atom.

I must apologise to the organic chemists among my audience for inflicting on them this very elementary exposition of what to them is a well-known theory. But outside the circle of organic chemists the theory is, I fear, far from well known. Thus, an eminent physicist, in his 'Theory of Light,' referring to the rotation of the plane of polarisation by liquid or dissolved substances, says: 'I am not aware that any explanation of it has ever been suggested.' And in the 'Proceedings of the Royal Society' for the present year, another eminent physicist, after quoting with approval this purely personal confession, goes on to suggest the possibility of the molecules having a twisted structure, and points out that a right-handed twist 'would appear right-handed when looked at from either end,' apparently unaware that such conceptions have been commonplaces of stereochemistry for the past quarter of a century at least.

This brief sketch of the theory was therefore necessary in order that we may now effectively discuss Pasteur's views on the relation between optical activity and life.

Whenever we prepare artificially, starting either with the elements, or with symmetric compounds, any organic compound which, when it occurs as a natural product of the living organism, is optically active, the primary product of our laboratory reactions, however closely it may in other respects resemble the natural product, differs from it in being optically inactive. Pasteur was greatly impressed by this fact. In the Lectures delivered in 1860 he says: 'Artificial products have no molecular asymmetry; and I could not point out the existence of any more profound distinction between the products formed under the influence of life, and all others.' And again, he refers to 'the molecular asymmetry of natural organic products' as 'the great characteristic which establishes perhaps the only well-marked line of demarcation that can at present be drawn between the chemistry of dead matter and the chemistry of living matter.' He would not admit that even racemoid forms, optically inactive by intermolecular compensation, might be

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[1] The asymmetric carbon atom is represented by an italic *C*.

artificially prepared; thus, to the suggestion that the malic acid which he had obtained from Dessaignes's artificial aspartic acid might possibly be the racemoid form (as we now know that it is), he replied: 'That is improbable, for then not only should we have made an active body from an inactive one, but we should have made two —a right and a left.'

The view that racemoids could not be prepared artificially did not long remain tenable. In 1860, the year in which the foregoing lectures were delivered, Perkin and Duppa, and, independently, Kekulé, obtained from dibromsuccinic acid a form of tartaric acid which Pasteur recognised as racemic acid. But the succinic acid employed had been prepared from amber, a substance of vegetable origin; and there was still the possibility that herein lay the source of the optical activity of the two constituents of the artificial racemic acid. This objection, which was raised by Pasteur himself, fell to the ground when, in 1873, Jungfleisch prepared racemic acid from Maxwell Simpson's synthetic succinic acid, and separated it into its right and left constituents by means of the sodium ammonium salt.

'Thus falls the barrier,' wrote Schützenberger, 'which M. Pasteur had placed between natural and artificial products. This example shows us how reserved we must be in attempting to draw distinctions between the chemical reactions of the living organism and those of the laboratory.'

To these words, which, although written a quarter of a century ago, may fairly be taken as representing the prevailing belief of chemists at the present day, Pasteur replied as follows:

> 'Contrary to M. Schützenberger's belief, this barrier still exists. . . . To transform *one inactive compound into another inactive compound* which has the power of resolving itself simultaneously into a right-handed compound and its opposite (*son symétrique*), is in no way comparable with the possibility of transforming *an inactive compound into a single active compound.* This is what no one has ever done; it is, on the other hand, what living Nature is doing unceasingly before our eyes.'

On this and subsequent occasions Pasteur did little more than reiterate opinions which he had previously expressed. As he himself stated, he was then occupied with other problems which absorbed his entire time and energies. The result has been that the opinions have suffered neglect and even misrepresentation. Thus Ostwald, in his 'Allgemeine Chemie,' translating, or rather paraphrasing, the foregoing passage, omits the word 'single'—which is the key to Pasteur's meaning—and then condemns the statement as illogical.

Pasteur's point is, that whereas living Nature can make a *single* optically active compound, those laboratory reactions, to which we resort in synthesising such compounds, always produce, simultaneously, at least *two*, of equal and opposite optical activity; the result being intermolecular compensation and consequent optical inactivity. Not necessarily implied in Pasteur's statement, but entirely in harmony with it, is the fact that we can sometimes produce artificially a single compound containing within its molecule two equal and opposite asymmetric groups, and therefore inactive by *intra*molecular compensation; thus in the oxidation of maleic acid to mesotartaric acid.

Let us consider the cause of this limitation of our synthetic reactions. Why cannot we produce, by laboratory processes, involving the play of symmetric forces and the interaction of symmetric atoms and molecules, *single* optically active compounds? To answer that question, let us turn our attention to the mechanism of the change in which a symmetric carbon atom becomes asymmetric.

A simple case of such a change, typical of all similar changes, is the transformation of a compound, $CH_2X'Y'$, by substitution, into $CHX'Y'Z'$. If we follow this process by means of our tetrahedral model, we see at once why, in our ordinary laboratory reactions, both enantiomorphs must be generated in equal quantity. The molecule of the compound, $CH_2X'Y'$, of which the tetrahedral representation is given in fig. 3, has, as we have already seen, a plane of symmetry passing through $X'Y'$ and the carbon atom; and from this plane of symmetry the two hydrogen atoms are equidistant on opposite sides. Any purely mechanical, symmetric force, therefore—any force, for example, such as comes into play in the motions of the symmetric molecules of a gas or a liquid—which affects one of these hydrogen atoms in one molecule of the compound $CH_2X'Y'$, has an equal chance of affecting the other hydrogen atom in another molecule. If the right-hand hydrogen atom in fig. 3 is replaced by the radicle Z′, we obtain the enantiomorph represented in fig. 1; if the left-hand hydrogen atom, that represented in fig. 2. The chances in favour of these two events being equal, the ratio,

$$\frac{\text{Number of occurrences of event I.}}{\text{Number of occurrences of event II.}}$$

will, if we are dealing with an infinitely great number of molecules, approximate to unity. We therefore obtain a mixture, optically inactive by intermolecular compensation.

All cases of the conversion of symmetric into asymmetric compounds may be referred to the same category, no matter whether the chemical process is one of substitution or of addition, or whether the resulting molecule contains one or more asymmetric carbon atoms. Thus, in the reduction of a ketone of the formula $X'.CO.Y'$ to a secondary alcohol of the formula $X'.\mathit{C}H(OH).Y'$; in the transformation of an aldehyde by the addition of hydrocyanic acid into a nitrile of an a-hydroxy-acid; in the oxidation of fumaric acid to racemic acid—cases typifying the various additive processes in which asymmetric groupings are produced—there is one condition common to all: in the symmetric compound, with which we start, there are, in every case, two identical points of attack, equidistant from the plane of symmetry of the molecule, and the result is that the two possible events happen in equal number, so that the mixture of enantiomorphs obtained is optically inactive by compensation. We are, of course, in many cases able afterwards to separate these enantiomorphs by the methods devised by Pasteur, and thus obtain the single optically active compounds; but we cannot produce them singly as long as we have at our disposal only the symmetric forces which we command in the laboratory.

Precisely the same state of things prevails when symmetric molecules unite, under the influence of symmetric forces, to build up an asymmetric crystalline structure. When, for example, sodium chlorate crystallises from its aqueous solution, the number of right-handed crystals is, on the average, as was shown by Kipping and Pope, equal to the number of left-handed crystals. The same fact was proved by Landolt by observing the optical inactivity of the mixture of microscopic right and left crystals obtained by adding alcohol to a concentrated aqueous solution of sodium chlorate. The two possible asymmetric events occur in equal number.

Non-living, symmetric forces, therefore, acting on symmetric atoms or molecules, cannot produce asymmetry, since the simultaneous production of two opposite asymmetric halves is equivalent to the production of a symmetric whole, whether the two asymmetric halves be actually united in the same molecule, as in the case of mesotartaric acid, or whether they exist as separate molecules, as in the left and right constituents of racemic acid. In every case, the symmetry of the whole is proved by its optical inactivity.

The result is entirely different, however, when we allow symmetric forces to act under the influence of already existing asymmetric, non-racemoid compounds.

Thus, if we start with an optically active compound—a compound containing one or more asymmetric carbon atoms and non-racemoid—and, by appropriate chemical reactions, render asymmetric some carbon atom in the compound which was not previously so, then it does not follow that the two forms represented by the two possible arrangements of this new asymmetric carbon atom will be produced in equal quantity. The compound with which we start has no plane of symmetry; and, although there are still the two possible points of attack, one will be more exposed than the other; in fact, one mode of attack may so predominate that apparently only one asymmetric compound is formed, the other compound, if formed at all, escaping detection by the smallness of its amount. A case in point is the conversion of *d*-mannose by combination with hydrocyanic acid into the nitrile of *d*-mannoheptonic acid, studied by Emil Fischer, in which only one nitrile is formed, although there are two ways in which the hydrocyanic acid may attach itself to the aldehyde group of the mannose. On the other hand, the same general reaction, in the union of hydrocyanic acid with ordinary aldehyde $CH_3.CHO$ —a symmetric compound—yields the right and left forms of lacto-nitrile $CH_3.\mathit{C}H(OH).CN$ in equal quantity, the two asymmetric events occurring in equal number, and the resulting mixture of compounds being inactive. It is the difference between guidance and no guidance: the asymmetric group present in the mannose guides into a particular path the symmetric forces which bring about the addition of the hydrocyanic acid; in the case of the symmetric aldehyde the result is left to pure chance. The latter action is like that of tossing a perfectly balanced coin; in the former the coin is heavily weighted on one side. The saying, '*les dés de la Nature sont pipés*,' is certainly true of living Nature and its products.

This guiding action displayed by asymmetric compounds may even impart a bias to the crystallisation of those molecularly symmetric substances already referred to, which crystallise in enantiomorphous forms. Thus, Kipping and Pope have recently made the interesting observation that the crystals of sodium chlorate which are deposited from an aqueous solution containing 200 grams of *d*-glucose to the litre consist, on an average, of about 32 per cent. of right-handed to 68 per cent. of left-handed crystals, the asymmetric carbohydrate, by its mere presence, favouring the formation of the one asymmetric form of the inorganic salt at the expense of the other.

These observations possibly afford a clue to the mode of action of the living organism in producing single enantiomorphs. This production of single asymmetric forms may be a result of the asymmetric character of the chemical compounds of which the tissues of plants and animals are built up. The optically active products of the organism—the carbohydrates, the terpenes, tartaric acid, asparagine, quinine, the serum of the blood, and countless others—have been formed in an asymmetric environment, and their asymmetry is an induced phenomenon. They have been cast, as it were, in an asymmetric mould. According to this view they are a result of the selective production of one of the two possible enantiomorphous forms. The same would hold good with regard to the organised tissues themselves, developed from inherited asymmetric beginnings in the ovum or the seed, or obtained by fission. The perplexing question of the *absolute origin* of these asymmetric compounds I will discuss later.

Another view has been put forward by Emil Fischer. In his lecture on 'Syntheses in the Sugar Group,' delivered before the German Chemical Society in 1890, he says:

> 'Starting with formaldehyde, chemical synthesis leads, in the first instance, to the optically inactive acrose. In contradistinction to this only the active sugars of the *d*-mannitol series have hitherto been found in plants.
>
> 'Are these the only products of assimilation [of carbon dioxide and water]? Is the preparation of optically active substances a prerogative of the living organism; is a special cause, a kind of vital force, at work here? I do not think so, and incline rather to the view that it is only the imperfection of our knowledge which imports into this process the appearance of the miraculous.
>
> 'No fact hitherto known speaks against the view that the plant, like chemical synthesis, first prepares the inactive sugars; that it then resolves them into their active constituents, using the members of the *d*-mannitol series in building up starch, cellulose, inulin, &c., whilst the optical isomerides serve for other purposes at present unknown to us.'

There are, therefore, two opposite processes which would account for the presence of optically active compounds among the substances generated in the living organism, and which we may briefly describe as *selective production* and *selective consumption*. An instance of artificial selective production is the formation of only one nitrile of *d*-mannoheptonic acid already cited. Selective consumption, dissociated, however, from the previous production of the racemoid form, may be illustrated by the fermentation of dextro-tartaric acid in the action, studied by Pasteur and already referred to, of a mould on racemic acid, the lævo-tartaric acid remaining untouched, and by numerous similar fermentations since discovered. Selective consumption is not restricted to living ferments; various cases are known of enzymes, or soluble ferments, which can effect the hydrolysis of one glucoside, but not of its enantiomorph. As Emil Fischer, who studied this phenomenon, says: 'Enzyme and glucoside must fit each other like key and lock, in order that the one may exercise a chemical action on the other.' And a similar selective action, embracing the much more complex phenomenon of alcoholic fermentation, is displayed by E. Buchner's soluble zymase obtained from yeast cells.

It is true, moreover, that the organism sometimes produces both enantiomorphs. Thus the lactic ferment converts carbohydrates into racemoid lactic acid; ordinary, or lævo-rotatory, asparagine is accompanied in plants, as Piutti showed, by a small quantity of its optical isomeride; and there are other cases.

These facts might be taken as evidence in favour of Fischer's view that selective consumption is the cause of the phenomenon we are discussing. But I do not think that, in the present state of our knowledge, we can decide between the two views. For that matter both may be correct, each may explain particular cases. What I wish to point out is that Fischer's statement that the 'miraculous' character of the phenomenon is eliminated by his assumption appears open to question. It is just as much, or as little, miraculous after as before. The production of a single asymmetric form, and the destruction of one of two opposite asymmetric forms, are problems of precisely the same order of difficulty, and there are only two ways in which either of them has ever been solved: firstly, by the direct action of living matter, and, secondly, by the use of previously existing asymmetric non-racemoid compounds, which are, in the last resort, due to the action of life. Directly or indirectly, then, life intervenes.

Doubtless this will appear a very extraordinary statement in view of Jungfleisch's synthesis of racemic acid and its resolution into dextro- and lævo-tartaric acids by the crystallisation of the sodium ammonium salts. The process does not take place in a living organism; nor is the aid of life invoked in the shape of a micro-organism as in Pasteur's third method of separation. No asymmetric base of vegetable origin is employed as in Pasteur's second method, so that the indirect action of life through its products is also excluded; sodium and ammonium are symmetric inorganic radicles, and no substance of one-sided asymmetry is introduced from beginning to end. The process is one of ordinary crystallisation; the two forms are deposited side by side, the operator afterwards picking out the right and left crystals and separating them. The reason why the two tartrates crystallise out and not the racemate, is that at the ordinary temperature of the air at which the crystallisation is conducted they are less soluble than the racemate. At a higher temperature, on the other hand, these solubilities are reversed and the racemate is deposited. The conditions are precisely those which govern the formation or non-formation of ordinary double salts.

Consequently, the overwhelming majority of chemists hold that the foregoing synthesis and separation of optically active compounds have been effected without the intervention of life, either directly or indirectly. Every manual of stereochemistry emphasises this point.

I have already hinted that I hold a contrary opinion. I have held it for some time, but have not ventured to give public expression to it, except in lecturing to my students. I was deterred chiefly by the impression that I stood alone in my belief. I find, however, that this was a mistaken impression. In a lecture on 'Pasteur as the Founder of Stereochemistry,' which Professor Crum Brown delivered before the Franco-Scottish Society in July 1897, and which is published in the 'Revue française d'Édimbourg,' he says, referring to the separation of enantiomorphs by crystallisation:—

'The question has often occurred to me: Do we here get rid of the action of a living organism? Is not the observation and deliberate choice by which a human being picks out the two kinds of crystals and places each in a vessel by itself the specific act of a living organism of a kind not altogether dissimilar to the selection made by *Penicillium glaucum*? But I do not insist on this, although I think it is not unworthy of consideration.'

It is this question, so precisely posed by Professor Crum Brown, that I would discuss in detail. I think we shall find that the answer to it will be in the sense which he indicates. The action of life, which has been excluded during the previous stages of the process, is introduced the moment the operator begins to pick out the two enantiomorphs.

It will doubtless be objected that, if this is the case, there can be no such thing as a synthesis of a naturally occurring organic compound without the intervention of life, inasmuch as the synthetic process is always carried out by a living operator.

Here, however, we must draw an important distinction. In the great majority of the operations which we carry out in our laboratories—such as solution, fusion, vaporisation, oxidation, reduction and the like—we bring to bear upon matter symmetric forces only—forces of the same order as those involved in the chance motions of the molecules of a liquid or a gas. All such processes, therefore, might conceivably take place under purely chance conditions, without the aid of an operator at all. But there is another class of operations, to which Pasteur first drew attention: those into which one-sided asymmetry enters, and which deal either with the production of a single enantiomorph, or with the destruction (or change) of one enantiomorph in a mixture of both, or with the separation of two enantiomorphs from one another. We have already seen that such processes are possible only under one-sided asymmetric influences, which may take the form either of the presence of an already existing enantiomorph, or of the action of a living organism, or of the free choice of an intelligent operator. They cannot conceivably occur through the chance play of symmetric forces.

We must, therefore, in classifying the actions of the intelligent operator, distinguish between those actions in which his services might conceivably be dispensed with altogether and those in which his intelligence is the essential factor. To the former class belongs the carrying out of symmetric chemical reactions; to the latter, the separation of enantiomorphs.

Take the synthesis of formic acid—a symmetric compound—by the absorption of carbon monoxide by heated caustic alkali. Given a forest fire and such naturally occurring materials as limestone, sodium carbonate, and water, it would not be difficult to imagine a set of conditions under which a chance synthesis of sodium formate from inorganic materials might occur. I do not assert that the conditions would be particularly probable; still, they would not be inconceivable. But the chance synthesis of the simplest optically active compound from inorganic materials is absolutely inconceivable. So also is the separation of two crystallised enantiomorphs under purely symmetric conditions.

The picking out of the two enantiomorphs is, moreover, to be distinguished from the process of similarly separating the crystals of two different non-enantiomorphous substances, although this distinction is commonly ignored by classing both processes together as *mechanical,* in opposition to *chemical* separations. In the case of the non-enantiomorphs there may be differences of solubility, of specific gravity and the like; so that other means of separation, involving only the play of symmetric forces, may be resorted to. Such a process may justly be regarded as 'mechanical.' But the two crystallised enantiomorphs, as we have seen, have the same solubility—at least in symmetric solvents; the same specific gravity; behave, in fact, in an identical manner towards all symmetric forces; so that no separation by such means is feasible. It requires the living operator, whose intellect embraces the conception of opposite forms of asymmetry, to separate them. Such a process cannot, by any stretch of language, be termed 'mechanical.' Conscious selection here produces the same result as the unconscious selection exercised by the micro-organism, the enzyme, or the previously existing asymmetric compound.

I need not point out that if the operator chooses to bring about the separation by an asymmetric solvent, or some other asymmetric means, he is still making use of his conception of asymmetry. He merely effects his end indirectly instead of directly. But in either case he exercises a guiding power which is akin, in its results, to that of the living organism, and is entirely beyond the reach of the symmetric forces of inorganic nature.

In like manner, it is not of the least consequence, for the purposes of the present argument, whether the micro-organism, with which we have compared the operator, acts directly in fermenting one of two enantiomorphs, or whether it acts indirectly by first preparing an asymmetric enzyme which displays this selective action. The contention, therefore, of E. Fischer, Buchner, and others, that the discovery of enzymes and zymases 'has transferred the phenomena of fermentation from biological to purely chemical territory,' is true only as regards the immediate process, and leaves intact the *vitalistic origin* of these phenomena.

We thus arrive at the conclusion that the production of single asymmetric compounds, or their isolation from the mixture of their enantiomorphs, is, as Pasteur firmly held, the prerogative of life. Only the living organism with its asymmetric tissues, or the asymmetric products of the living organism, or the living intelligence with its conception of asymmetry, can produce this result. Only asymmetry can beget asymmetry.

Is the failure to synthesise single asymmetric compounds without the intervention, either direct or indirect, of life due to a permanent inability, or merely to a temporary disability which the progress of science may remove? Pasteur took the latter view, and suggested that the formation of chemical compounds in the magnetic field, or under the influence of circularly polarised light, would furnish a means of solving the problem; and Van't Hoff also thinks the latter method feasible. As regards magnetism, Pasteur's suggestion was undoubtedly based on a misconception; the magnetic field has not an asymmetric structure; it is merely polar, since the rotation which it produces in the plane of polarisation of a ray of light changes sign with the direction of the field. As regards circularly polarised light, I must confess to having doubts as to whether it can be regarded as an asymmetric phenomenon: the motion of the ether about the axis of the ray is circular, not spiral; and it is only by considering the difference of phase from point to point along the ray that the idea of a spiral can be evolved from it. In fact, are there such things as forces asymmetric in themselves? Is the geometrical conception of asymmetry applicable to dynamical phenomena at all, except in so far as these deal with asymmetric material structures, such as quartz crystals, or organic molecules containing asymmetric carbon atoms? But this is a question which I would submit to the judgment of mathematical physicists.

One thing is certain—namely, that all attempts to form optically active compounds under the influence of magnetism or circularly polarised light have hitherto signally failed. These forces do not distinguish between the two equally exposed points of attack which present themselves in the final stage of the transformation of a symmetric into an asymmetric carbon atom.

But even if such an asymmetric force could be discovered—a force which would enable us to synthesise a single enantiomorph—the process would not be free from the intervention of life. Such a force would necessarily be capable of acting in two opposite asymmetric senses; left to itself it would act impartially in either sense, producing, in the end, both enantiomorphs in equal amount. Only the free choice of the living operator could direct it consistently into one of its two possible channels.

I will briefly recapitulate the conclusions at which we have arrived. Non-living, symmetric matter—the matter of which the inorganic world is composed—interacting under the influence of symmetric forces to form asymmetric compounds, always yields either pairs of enantiomorphous molecules (racemoid form), or pairs of enantiomorphous groups united within the molecule (meso-form), the result being, in either case, mutual compensation and consequent optical inactivity. The same will hold good of symmetric matter interacting under the influence of asymmetric forces (supposing that such forces exist) provided that the latter are left to produce their effect under conditions of pure chance.

If these conclusions are correct, as I believe they are, then the *absolute origin* of the compounds of one-sided asymmetry to be found in the living world is a mystery as profound as the absolute origin of life itself. The two phenomena are intimately connected, for, as we have seen, these symmetric compounds make their appearance with life, and are inseparable from it.

How, for example, could lævo-rotatory protein (or whatever the first asymmetric compound may have been) be spontaneously generated in a world of symmetric matter and of forces which are either symmetric or, if asymmetric, are asymmetric in two opposite senses? What mechanism could account for such selective production? Or if, on the other hand, we suppose that dextro- and lævo-protein were simultaneously formed, what conditions of environment existing in such a world could account for the survival of the one form and the disappearance of the other? Natural selection leaves us in the lurch here; for selective consumption is, under these conditions, as inconceivable as selective production.

No fortuitous concourse of atoms, even with all eternity for them to clash and combine in, could compass this feat of the formation of the first optically active organic compound. Coincidence is excluded, and every purely mechanical explanation of the phenomenon must necessarily fail.

I see no escape from the conclusion that, at the moment when life first arose, a directive force came into play—a force of precisely the same character as that which enables the intelligent operator, by the exercise of his Will, to select one crystallised enantiomorph and reject its asymmetric opposite.

I would emphasise the fact that the operation of a directive force of this nature does not involve a violation of the law of the conservation of energy. Enantiomorphs have the same heat of formation; the heat of transformation of one form into the other is nil. Whether, therefore, one enantiomorph alone is formed, or its optical opposite alone, or a mixture of both, the energy required per unit weight of substance is the same. There will be no dishonoured drafts on the unalterable fund of energy.

The interest of the phenomena of molecular asymmetry from the point of view of the biologist lies in the fact that they reduce to its simplest issues the question of the possibility or impossibility of living matter originating from dead matter by a purely mechanical process. They reduce it to a question of solid geometry and elementary dynamics; and therefore, if the attempted mechanical explanation leads to a *reductio ad absurdum*, this ought to be of a correspondingly simple and convincing character. Let us see how far this is the case.

Life is a phenomenon of bewildering complexity. But in discussing the problem of the origin of life this complexity cuts two ways. Whilst, on the one hand, it is appealed to by one set of disputants as an argument against the mechanical theory, on the other it affords shelter for the most unproved statements of their opponents. I will take a concrete instance from the writings of an upholder of the mechanical theory of the origin of life, the late Professor W. K. Clifford. He says:

> 'Those persons who believe that living matter, such as protein, arises out of non-living matter in the sea, suppose that it is formed like all other chemical compounds. That is to say, it originates in a coincidence, and is preserved by natural selection. . . . The coincidence involved in the formation of a molecule so complex as to be called *living*, must be, so far as we can make out, a very elaborate coincidence. But how often does it happen in a cubic mile of sea-water? Perhaps once a week; perhaps once in many centuries; perhaps, also, many million times a day. From this living molecule to a speck of protoplasm visible in the microscope is a very far cry; involving, it may be, a thousand years or so of evolution.'

It was easy for Clifford to write thus concerning life itself, for it was difficult for any one to contradict him. But had he been asked whether any mechanical (symmetric) coincidence would suffice to convert an infinitely great number of molecules of the type shown in fig. 3 into that shown in (say) fig. 1, to the exclusion of that shown in fig. 2; or whether, given a mixture, in equal proportions, of molecules of the types shown in figs. 1 and 2, any mechanical (symmetric) conditions of environment would bring about the destruction of one kind and the survival of the other, I think his exact mathematical and dynamical knowledge would have prevented him from giving an affirmative answer. But short of this affirmative answer, his other statements, it seems to me, fall to the ground.

I am convinced that the tenacity with which Pasteur fought against the doctrine of spontaneous generation was not unconnected with his belief that chemical compounds of one-sided asymmetry could not arise save under the influence of life.

Should any one object that the doctrine of the asymmetric carbon atom is a somewhat hypothetical foundation on which to build such a superstructure of argument as the foregoing, I would point out that the argument is in reality independent of this doctrine. All that I have said regarding the *molecular* asymmetry of naturally occurring optically active organic compounds, and all the geometrical considerations based thereon, hold good equally of the hemihedral *crystalline* forms of these compounds, about which there is no hypothesis at all. The production of a compound crystallising in one hemihedral form to the exclusion of the opposite hemihedral form, as in the case of the tartaric acid of the grape, is a phenomenon inexplicable on the assumption that merely mechanical, symmetric forces are at work. Nor is this conclusion invalidated even if we ultimately have to admit that the connection between molecular and crystalline asymmetry is not an invariable one—a point about which there is some dispute.

At the close of the lectures from which I have so frequently quoted, Pasteur, with full confidence in the importance of his work, but without any trace of personal vanity, says:—

> 'It is the theory of molecular asymmetry that we have just established—one of the most exalted chapters of science. It was completely unforeseen, and opens to physiology new horizons, distant but sure.'

I must leave physiologists to judge how far they have availed themselves of the new outlook which Pasteur opened up to them. But if I have in any way cleared the view towards one of these horizons, I shall feel that I have not occupied this chair in vain.

Some of my hearers, however, may think that, instead of rendering the subject clearer, I have brought it perilously near to the obscure region of metaphysics; and certainly, if to argue the insufficiency of the mechanical explanation of a phenomenon is to be metaphysical, I must plead guilty to the charge. I will, therefore, appeal to a judgment—metaphysical, it is true, but to be found in a very exact treatise on physical science—namely, Newton's 'Principia.' It has a marked bearing on the subject in hand:—

> '*A cæca necessitate metaphysica, quæ utique eadem est semper et ubique, nulla oritur rerum variatio.*'

I will merely add that this is certainly true of the particular *rerum variatio* in which optically active organic compounds originate.

The following Papers and Reports were read:—

1. *On the Extraction from Air of the Companions of Argon and on Neon. By* WILLIAM RAMSAY *and* MORRIS W. TRAVERS.

In the Presidential Address to the Chemical Section of this Association, delivered last year at Toronto, it was pointed out that the densities of helium and argon being respectively 2 and 20 in round numbers, and the ratio of their specific heats being in each case 1·66, their atomic weights must be respectively 4 and 40. If the very probable assumption is made that they belong to the same group of elements, it appears almost certain on the basis of the Periodic Table that another element should exist, having an atomic weight higher than that of helium by about 16 units, and lower than that of argon by about 20. There is also room for elements of higher atomic weight than argon, belonging to the same series. The search for this element was described in last year's Address, and, it will be remembered, the results were negative.

Reading between the lines of the Address, an attentive critic might have noticed that no reference was made to the supposed homogeneity of argon. From speculations of Dr. Johnstone Stoney, it would follow that the atmosphere of our planet might be expected to contain new gases, if such exist at all, with densities higher than 8 or thereabouts. Dr. Stoney gives his reasons for supposing that the lighter the gas the less its quantity in our atmosphere, always assuming that no chemical compounds are known which would retain it on the earth, or modify its relative amount. Therefore it appeared worthy of inquiry whether it was possible to separate light and also heavy gases from argon.

The beautiful machine invented by Dr. Hampson has put it in our power to obtain, through his kindness and that of the 'Brin' Oxygen Company, large quantities of liquid air. We were therefore able to avail ourselves of the plan of liquefaction, and subsequent fractional distillation, in order to separate the gases.

On liquefying 18 litres of argon, and boiling off the first fraction, a gas was obtained of density 17 $(O=16)$. This gas was again liquefied and boiled off in six fractions. The density of the lightest fraction was thus reduced to 13·4, and it showed a spectrum rich in red, orange, and yellow lines, differing totally from that of argon. On re-fractionating, the density was reduced further to 10·8; the gas still contained a little nitrogen, on removing which the density decreased to 9·76. This gas is no longer liquefiable at the temperature of air boiling under a pressure of about 10 millimetres; but if, after compression to two atmospheres, the pressure was suddenly reduced to about a quarter of an atmosphere, a slight mist was visible in the interior of the bulb. This gas must necessarily have contained argon, the presence of which would obviously increase its density; and in order to form some estimate of its true density, some estimate must be made of the relative amount of the argon. We have to consider a mixture of neon, nitrogen, and argon, the two latter of which are capable, not merely of being liquefied, but of being solidified without difficulty. Under atmospheric pressure nitrogen boils at $-194°$, and solidifies at $-214°$, and the boiling-point of argon is $-187°$, and the freezing-point $-190°$; the vapour-pressure of nitrogen is therefore considerably higher than that of argon. The mist produced on sudden expansion consisted of solid nitrogen and argon; and for want of better knowledge, assuming the vapour-pressure of the mixture of nitrogen and argon to be the sum of the partial pressures of the two, it is obvious that that of argon would form but a small fraction of the whole. The vapour-pressure of argon was found experimentally to be 109 millimetres at the temperature of air boiling in as good a vacuum as could be produced by our pump; but as we have only to consider the partial pressure of the argon at a much lower temperature, we do not believe that the pressure of the argon can exceed 10 millimetres in the gas. This would correspond to a density for neon of 9·6.

The ratio between the specific heat at constant pressure and constant volume was determined for neon in the usual way, and, as was to be expected, it approximates closely to the theoretical ratio, being 1·655. We therefore conclude that, like helium and argon, the gas is monatomic.

It may be remembered that the refractivity of helium compared with that of air is exceptionally low—viz., 0·1238. The lighter gas, hydrogen, has a refractivity of 0·4733. It was to be expected from the monatomic character and low density of neon that its refractivity should be also low; this expectation has been realised, for the number found is 0·3071. Argon, on the other hand, has a refractivity not differing much from that of air—viz., 0·958. Since the sample of neon certainly contains a small amount of argon, its true refractivity is probably somewhat lower. Experiments will be carried out later to ascertain whether neon resembles helium in its too rapid rate of diffusion.

The spectrum of neon is characterised by brilliant lines in the red, the orange, and the yellow. The lines in the blue and violet are few, and comparatively inconspicuous. There is, however, a line in the green, of approximate wave-length 5,030, and another of about 5,400.

A few words may be said on the other companions of argon. The last fractions of liquefied argon show the presence of three new gases. These are krypton, a gas first separated from atmospheric air, and characterised by two very brilliant lines, one in the yellow and one in the green, besides fainter lines in the red and orange; metargon, a gas which shows a spectrum very closely resembling that of carbon monoxide, but characterised by its inertness, for it is not changed by sparking with oxygen in presence of caustic potash; and a still heavier gas, which we have not hitherto described, which we propose to name 'xenon.' Xenon is very easily separated, for it possesses a much higher boiling-point, and remains behind after the others have evaporated. This gas, which has been obtained practically free from krypton, argon, and metargon, possesses a spectrum analogous in character to that of argon, but differing entirely in the position of the lines. With the ordinary discharge the gas shows three lines in the red, and about five very brilliant lines in the blue; while with the jar and spark-gap these lines disappear, and are replaced by four brilliant lines in the green, intermediate in position between the two groups of argon lines, the glow in the tube changing from blue to green. Xenon appears to exist only in very minute quantity.

Indeed, all of these gases are present only in small amount. It is, however, not possible to state with any degree of accuracy in what proportion they are present in atmospheric argon. Of neon, perhaps, we may say that the last fraction of the lightest hundred cubic centimetres from 18 litres of atmospheric argon no longer shows the neon spectrum, and possesses the density of argon; it may be safe to conclude, therefore, that 18 litres of argon do not contain more than 50 cubic centimetres of neon; the proportion of neon in air must therefore be about one part in 40,000. We should estimate the proportion of the heavy gases at even less.

It follows from these remarks that the density of argon is not materially changed by separating from it its companions. A sample of gas, collected when about half the liquid argon or about 10 cubic centimetres had boiled off, possessed the density 19·89; the density of atmospheric argon is 19·94. But, of course, we give this density of argon as only provisional;[1] for a final determination the density must be determined after more thorough fractionation.

With a density of 9·6, and a consequent atomic weight of 19·2, neon would follow fluorine and precede sodium in the Periodic Table; as to the other gases, further research will be required to determine what position they hold.

[October 10, 1898.—The sample of neon alluded to above has since been found to contain a small trace of helium. The presence of this light gas has no doubt made the density of neon given in this communication somewhat too low. The actual density has not yet been determined, but the density will obviously not be materially altered.—W. R.]

2. *On the Position of Helium, Argon, Krypton, &c., in the Periodic Classification of the Elements. By* Professor J. EMERSON REYNOLDS, *F.R.S.*

3. *Report on the Electrolytic Methods of Quantitative Analysis.*

See Reports, p. 294.

4. *A new form of Stand for Electrolytic Analysis.*

By Dr. HUGH MARSHALL.

5. *Report on the Continuation of the Bibliography of Spectroscopy.*

See Reports, p. 439.

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[1] July 30, 1898.

FRIDAY, SEPTEMBER 9.

The following Papers and Report were read:—

1. *Some Researches on the Thermal Properties of Gases and Liquids. By* SYDNEY YOUNG, *D.Sc., F.R.S., University College, Bristol.*

Gases under moderate or low pressures are characterised by the simplicity of the laws relating to the variation of their volume with temperature and pressure. But when the pressure is greatly increased, these laws no longer hold good; at constant temperature the product pv, instead of remaining constant, diminishes until a minimum is reached, and at still higher pressures increases again, and this increase continues up to the highest pressures that have been reached.

A most important advance in the explanation of the behaviour of compressed gases and of liquids was made just twenty-five years ago by Van der Waals, who, taking into account the two facts (1) that the molecules of a gas attract one another, (2) that they occupy a finite volume, and are not mere mathematical points, proposed the formula

$$\left(p+\frac{a}{v^2}\right)(v-b)=\mathrm{RT}$$

in place of the simple one $pv=\mathrm{RT}$. The formula of Van der Waals expresses very well the general relations of pressure, temperature, and volume for both gases and liquids, but does not give the actual values with sufficient accuracy, and many attempts have been made to alter it in such a way as to bring about a better agreement. It is noticeable that at constant volume the formula becomes $p=\mathrm{KT}-c$, where K and c are constants, depending on the volume, and this simple relation has been found to hold good for gases by Amagat, and for both gases and liquids by Ramsay and myself. Within the last few years I have investigated the behaviour of a hydrocarbon, isopentane,[1] through a very wide range of volume (1·6–4000 cc. per gram), and of normal pentane through a smaller range, and the data so obtained have led Rose-Innes [2] to a formula

$$p=\frac{\mathrm{RT}}{v}\left\{1+\frac{e}{v+k-gv^{-2}}\right\}-\frac{l}{v(v+k)},$$

based on the simple one $p=\mathrm{KT}-c$, which reproduces the observed isothermals from the largest volume to about 3·4 c.c. per gram, with a maximum error of slightly over 1 per cent.

A complete investigation of this kind requires, however, a large amount of time, and can only be carried out with very stable substances of comparatively low critical temperatures; and it occurred to me about eleven years ago that a careful study of certain generalisations, deduced by Van der Waals from his formula, might yield valuable results, and perhaps indicate the direction in which the formula requires alteration.

The generalisations may be stated thus:—If any two substances, A and B, are compared at pressures, P_A and P_B, proportional to their critical pressures, π_{0A} and π_{0B}, their boiling points (absolute temperatures), T_A and T_B, will be proportional to their critical temperatures, θ_{0A} and θ_{0B}, and their volumes, both as liquid, V_A and V_B, and as saturated vapour, v_A and v_B, will be proportional to their critical volumes, ϕ_{0A} and ϕ_{0B}. It would follow from this that at 'corresponding' pressures the ratios of the actual to the theoretical density of saturated vapour, $\frac{D}{D'}$, should be the same for all substances.

It is convenient to speak of the ratio of the pressure to the critical pressure as the 'reduced' pressure, π, the actual pressures, P_A, P_B, being called 'corresponding' pressures.

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[1] *Proc. Phys. Soc.*, vol. xiii. p. 602.

[2] *Ibid.*, vol. xv. p. 126; vol. xvi. p. 11.

I proposed, therefore, to determine the vapour pressures and the specific volumes (both as liquid and as saturated vapour) of a considerable number of substances from low temperatures to their critical points, and in the first place I chose some compounds of elements belonging to the same group in the periodic table, as it seemed possible that some points of interest might thus arise. The first substances I examined were the four monohaloid derivatives of benzene, as well as benzene itself,[1] and the result of the investigation was to show that, when the haloid derivatives are compared together, the generalisation, as regards temperature and pressure, hold good accurately; but there is this peculiarity about these compounds, that their critical pressures are equal, or very nearly so, and therefore 'corresponding' pressures are in this case equal pressures. The critical pressure of benzene itself is different, and when the hydrocarbon is compared with any of its haloid derivatives, the differences between the temperature ratios are much greater. As regards the volume ratios, the differences are small in all cases.

The only other substances, bearing on the periodic arrangement of the elements, which have been yet examined are the tetrachlorides of carbon and tin.[2] The critical pressures differ considerably, and the relationship resembles that of the normal paraffins to each other, which will be referred to later. Many of the chlorides of the elements are very hygroscopic, and attack mercury at high temperatures, and it was thought better to postpone their further examination, and to obtain the data for a few series of homologous organic compounds. Up to the present, in addition to the three lowest alcohols, investigated by Ramsay and myself, ten esters[3] and four paraffins[4] have been studied, and with the exception of the alcohols it has been observed in every case (and the same remark applies to the tetrachlorides of carbon and tin), that the ratios $\frac{T}{\theta_0}$ at any reduced pressure increase with rise of molecular weight. No definite relation is observable between the molecular weights and the ratios $\frac{V}{\phi_0}$ and $\frac{v}{\phi_0}$ in the case of the esters, but with the three normal paraffins (pentane, hexane, and heptane) and the two tetrachlorides, the ratios $\frac{v}{\phi_0}$ increase and $\frac{V}{\phi_0}$ diminish slightly with rise of molecular weight. With the alcohols, on the other hand, the ratios $\frac{T}{\theta_0}$ and $\frac{V}{\phi_0}$ are irregular and $\frac{v}{\phi_0}$ diminish.

Another point of interest is the comparison of isomeric compounds; but up to the present the only two pairs of isomers investigated are methyl butyrate and isobutyrate, and normal and iso-pentane. In both cases there is a clear relationship between the ratios and the constitution, the normal and iso-compounds standing to each other in much the same relative positions as a higher and lower normal paraffin.

It is worthy of remark that the volumes of a gram of all four paraffins are nearly the same (4·266 – 4·303) at the critical point.

Looking at the data for the twenty-six substances examined, it is evident that they may be divided into groups—(1) benzene and its haloid derivatives, ether, the tetrachlorides and the paraffins; (2) the ten esters; (3) the alcohols; (4) acetic acid. The members of group (1) may be regarded as normal; the deviations of the ratios from constancy are small, though, as pointed out, they exhibit certain regularities; in group (2) the values of $\frac{v}{\phi_0}$ are rather higher, and of $\frac{V}{\phi_0}$ rather lower than in group (1); in group (3) the ratios $\frac{T}{\theta_0}$ and $\frac{v}{\varphi_0}$ are very

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[1] *Trans. Chem. Soc.*, vol. lv. p. 486.

[2] *Ibid.*, vol. lix. p. 911.

[3] *Ibid.*, vol. lxiii. p. 1191.

[4] *Ibid.*, vol. lxvii. p. 1071; vol. lxxi. p. 446; vol. lxxiii. 675; *Proc. Phys. Soc.*, vol. xiii. p. 602.

high; for acetic aid $\frac{T}{\theta_0}$ and $\frac{V}{\phi_0}$ are high, but $\frac{v}{\phi_0}$ very low. The marked differences between the alcohols and acetic acid, and the large deviations in both cases, are probably to be accounted for by the fact that the molecules of the alcohols at moderate temperatures are polymerised in the liquid, but not the gaseous state, whilst with acetic acid there is polymerisation in both states.

The ratios $\frac{D}{D'}$ at the critical point should, according to Van der Waals, be the same for all substances, the molecules of which undergo no dissociation or polymerisation, and he gives the value of this ratio as $\frac{8}{3}$ or $2\cdot\dot{6}$. Now the ratio depends on the constant b in the equation

$$\left(p+\frac{a}{v^2}\right)(v-b)=RT,$$

and Van der Waals takes b to be four times the actual volume of the molecules in unit mass of substance; O. E. Meyer, however, contends that $b=4\times\sqrt{2}$ times the volume of the molecules, and it has been pointed out by Heilborn and by Guye that, if that is so, the ratio $2\cdot\dot{6}$ should also be multiplied by $\sqrt{2}$, which would give the value 3·77. It is remarkable that the mean value for the twelve substances in group (1) is 3·77, from which it may be concluded that the molecules of these substances in the critical state are simple like those of the gas. (At the same time it is to be noticed that with the three normal paraffins and the two tetrachlorides $\frac{D}{D'}$ shows a slight increase with rise of molecular weight.

The ratios for the ten esters are a little higher (3·87 to 3·95); decidedly higher for the alcohols, especially methyl-alcohol (4·52 – 4·02), and much higher for acetic acid (5·00). It would appear from this that the molecules of the alcohols and acetic acid are polymerised to a considerable extent at the critical point, and this conclusion is supported by the generally abnormal behaviour of these substances, and agrees with that of Ramsay and Shields, that in the liquid state at moderate temperatures their molecules are decidedly complex, whilst those of the majority of the compounds examined by them are probably simple.

I hope to continue the investigation of the paraffins and other hydrocarbons in order to obtain further light on the points referred to, and it will be of interest to compare the molecular volumes at the critical points, and at a series of reduced pressures.

The accurate determination of the critical constants is a matter of great importance. It is best to employ an apparatus similar in principle to that of Andrews, in which the temperature, pressure, and volume can be altered at will; though the critical temperature may be determined with but small error in a sealed tube, if the quantity of liquid taken is such that its critical volume is approximately equal to the capacity of the tube. With a pure substance, free from air, two independent determinations of the critical temperature should certainly not differ by 0°·1, unless the temperature is above 300°, when the experimental difficulties are greater. The error in the determination of the critical pressure should not exceed 0·2 per cent., but the critical pressure is greatly affected by the presence of even very small quantities of impurity (and, of course, of air); and in comparing two specimens of the same substance, one of which is known to be pure, the agreement of the critical pressure is probably the most delicate test of the purity of the other.

The only method yet known by which the critical volumes can be accurately determined is the indirect one based on the 'law of diameters' of Cailletet and Mathias. These physicists made the very important discovery that the mean densities of liquid and saturated vapour for any 'normal' substance are a linear function of the temperature (or $D = D_0 - a\,t$ where D = the mean density), and since, at the critical point, the two densities are equal—or rather there is only one—the value of D at that point gives the critical density, from which the critical volume is, of course, easily calculated. I have been able to show that the law of Cailletet and Mathias holds good with great accuracy right up to the critical point (with normal pentane observations were taken to within 0°·05 of the critical temperature) for all the compounds examined except the alcohols. It has, in view of these results, been suggested, I think justly, by M. Guye, that a serious deviation from the law may be taken as a proof of the existence of molecular dissociation or polymerisation.

It is true that a few years ago I was under the impression that a direct determination of the critical volume was possible, and the values obtained do, indeed, bear as nearly constant ratio to the true critical volume, but they are about 14 per cent. too low. The probable explanation of the error has been given by M. Gouy, who pointed out that, at the critical point, a substance is so extremely compressible that in a long column the density increases very considerably from top to bottom, owing to the pressure exerted by the substance itself.

In the course of these researches ample proof has been obtained that the views of Andrews regarding the behaviour of a substance in the neighbourhood of the critical point are correct, and also that the vapour pressure of a pure substance is quite independent of the relative volumes of liquid and vapour. These points are referred to because they have been called in question by several observers during the last few years.

Two of the substances examined attack mercury at high temperatures, and it was therefore impossible to determine either their vapour pressures or specific volumes by the methods employed for the other liquids. The difficulty, as regards vapour pressure, was overcome by sealing a wider tube to the lower end of the volume tube, and using such a quantity of liquid that during the observations the lower end of the column was always in the wider and cold part of the tube. The height of the column of mercury in the tube must, under these conditions, be calculated.[1]

A method of determining the specific volumes of both liquid and saturated vapour in a sealed tube was also devised.[2] When the specific volumes of the liquid are already known, this method, in a simplified form, is very convenient for determining the specific volumes of saturated vapour.[3]

It is obviously necessary that, in order to obtain trustworthy results, pure substances must be employed and, indeed, more time has been spent in the preparation of the pure substances than in the determination of their physical constants. The difficulties met with in the fractional distillation of liquids, more especially in the separation of pure hydrocarbons from petroleum, have led to an extended study of this subject, and both new apparatus [4] and new methods of procedure [5] have been devised; it has thus been possible to separate perfectly pure normal and iso-pentane (B. P. 27°·95 and 36°·3) from the complex mixture of hydrocarbons in American petroleum.

2. *On the Action of certain Metals and Organic Bodies on a Photographic Plate. By* W. J. Russell, *Ph.D., F.R.S.*

The author demonstrated that printers' ink is capable of acting, in the dark, on a photographic plate; also that wood, dry copal varnish, &c., can act in the same way; that among liquids turpentine, drying oil, the essential oils, &c., act in like manner. In addition to these and many other organic bodies, certain metals have the same property, and either in contact, or at a distance from the photographic plate, can act upon it. In this way pictures of thin surface or pictures of opaque bodies, such as skeleton leaves, lace, or paper, can be obtained. It was also shown that ordinary writing ink was perfectly opaque to this kind of action, and that even old and much faded ink was capable of stopping the action and producing a

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[1] *Trans. Chem. Soc.*, vol. lix. p. 917.

[2] *Ibid.*, vol lix. p. 37.

[3] *Ibid.*, vol. lix. p. 125; *Proc. Phys. Soc.*, vol. xiii. p. 617.

[4] *Chem. News*, vol. lxxi. p. 177; *Trans. Chem. Soc.*, vol. lxxi. p. 440.

[5] *Phil. Mag.*, 1894 p. 8.

picture. The author also demonstrated that the action could pass through such media as thin sheets of gelatine, celluloid, gutta-percha, collodion, &c., and that even a picture of a metal surface is obtainable through such media. It was suggested that these different phenomena could be explained on the supposition that hydrogen peroxide is in all cases produced.

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3. *The Action of Bacteria on the Photographic Plate. By* PERCY FRANKLAND, *Ph.D., B.Sc., F.R.S., Professor of Chemistry in Mason University College, Birmingham.*

The action on the photographic plate which is exerted by uranium and its compounds, by zinc and several other metals, as well as by a number of organic substances, naturally leads to the inquiry as to whether living structures may not also be endowed with the power of recording their presence by action on the sensitive film of the photographer. The author has opened up this inquiry by investigating the behaviour of bacterial cultures towards highly sensitive photographic plates.

Gelatine cultures of the *bacillus coli communis* and of *proteus vulgaris* were found when placed at a distance of half an inch from a photographic plate to produce the same effect as light, the exposure lasting over nine days in absolute darkness. Definite pictures of the bacterial cultures were obtained by placing the sensitive film in actual contact with the cultivations, the exposure being extended over a period of fourteen days. Similar results were obtained with agar-agar cultivations.

As this action does not take place through glass or mica, the author is of opinion that it is not due to any form of radiation, but to the evolution of volatile matter entering into reaction with the photographic film. As far as the author's experiments have gone, the action is exerted both by bacteria which liquefy (*proteus vulgaris*) and those which do not liquefy gelatine (*b. coli communis* and the typhoid bacillus). It is, however, quite possible that considerable differences in respect of this activity may be found to exist in the case of different bacteria, and that this property may become of importance in their diagnosis.

Bacterial growths which are luminous in the dark (*photo-bacterium phosphorescens*) were found to exert a still more powerful action on the photographic plate.

The author proposes extending these investigations not only in connection with bacteria but also in respect to other organised structures, vegetable and animal, living and dead.

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4. *Further Experiments on the Absorption of the Röntgen Rays by Chemical Compounds. By* J. H. GLADSTONE, *D.Sc., F.R.S., and* WALTER HIBBERT.

At the two previous meetings of the British Association the authors had examined the absorption of Röntgen rays, especially by metals and metallic salts. During the past year they have endeavoured to perfect the quantitative methods employed for estimating the comparative intensity of radiographs taken simultaneously; and to determine whether the amount of absorption is purely an atomic phenomenon, or whether the amount of rays absorbed by a compound body depends to any extent on its physical condition or manner of combination.

In the experiments recorded the authors had again employed the Lummer-Brodhun photometer; and had endeavoured to get rid of irregularities of exposure by placing the objects simultaneously exposed to be radiographed at a considerable distance from the radiating point (averaging 15 or 16 inches), and rotating them during the experiment. They believe that in this way the effect upon the sensitive plates can be determined within ± 2 per cent. An experiment was usually repeated about six times, and the mean taken.

Among the results arrived at were the following. Finely-pounded glass gave a radiograph about 3 per cent. deeper than the same quantity of the same class when in the form of a polished plate. Paraffin gave the same amount of absorption whether it was solid or liquid. Pounded crystals of sulphate of copper and ammonia gave practically the same absorption as a mere mixture of the two constituent salts. Finely-divided metallic copper was found to absorb about 2 per cent. more rays than the same amount of copper as black oxide or as red oxide. That there was little or no effect produced by difference of atomicity was shown by a comparison of these two oxides, and also of the two oxides of mercury, which absorbed practically the same amount. The protoxide and peroxide of lead were identical in their results; and the ferric oxalate gave only 1 per cent. less absorption than the ferrous oxalate, *plus* as much oxalic acid as was necessary to equalise the carbon and oxygen in the two salts.

The old experiment with carbon and various hydrocarbons was re-examined, with a final result which may be expressed by the figures:—

Carbon	solid, black	C	100
Anthracene	„ white	$C_{14}H_{10}$	96
Naphthalene	„ „	$C_{10}H_8$	93
Amyl hydride	liquid, colourless	C_5H_{12}	96·5
Turpentine.	„ „	$C_{10}H_{16}$	95
Benzene	„ „	C_6H_6	94·5

The experiments of this year confirm the opinion previously expressed that the absorption of the Röntgen rays by a compound body is dependent upon the absorption exercised by its constituents, little, if at all, modified by their physical condition, or by change of atomicity, or other difference of combination.

The authors are disposed, however, to ask the question—whether the law may not be more than proximately true? There is superabundant evidence that the Röntgen rays are not homogeneous. The slightly greater apparent absorption produced by the pounded glass may be due to a little reflection or refraction from the admixture of a small quantity of rays which, though they have passed through aluminum foil, have properties somewhat analogous to ordinary light. The slightly greater absorption caused by metallic copper and by black carbon may also be due to the presence of such rays.

They think it possible that if these rays could be entirely sifted away, Röntgen rays would be obtained, which in their passage through a body would be affected merely by the nature of the atoms forming it, and that the law that the absorption by a compound is the mean of the absorptions due to its several constituents would be not proximately but absolutely true.

An apparatus was exhibited by which the 'grade' of the Röntgen rays can be investigated quantitatively.

5. *Report on the Action of Light upon Dyed Colours.*—See Reports, p. 285.

6. *On the Cooling Curves of Fatty Acids. By* Dr. A. P. Laurie *and* E. H. Strange.

The melting-points of mixtures of fatty acids were determined by Heintz, and the tables are quoted in the text-books. They show that the mixtures have a lower melting-point than either of their constituents, thus showing a close analogy to the behaviour of many alloys. We therefore determined to apply to these bodies a method of investigation similar to that used by Professor Roberts Austen in his experiments on alloys.

The melted fatty acids are placed in a test-tube surrounded by melting ice, and a thermal junction connected to a mirror galvanometer inserted. The results are photographed on a moving plate. The plate is calibrated by means of a second thermal junction attached to a thermometer, and immersed in a large volume of water. The cooling curves obtained in this way are of considerable interest. The fatty acids investigated have been palmitic, stearic, lauric, and myristic acids. The cooling curve of a pure fatty acid turns sharply round when the solidifying point is reached, runs straight up the plate till the solidifying is finished, and then turns sharply off again. One per cent. of another fatty acid quite perceptibly alters the shape of the curve, so that the character of a cooling curve seems a good test of purity. When a larger portion of a fatty acid is introduced a second latent heat-point is developed, the curve showing a discontinuity below the solidifying point of the mixture. As the solidifying point is lowered by introducing more and more of the second fatty acid, this discontinuity is gradually merged in the common melting-point of the mixture, thus reproducing the phenomena observed by Professor Roberts Austen in the case of certain alloys. This discontinuity can hardly be due to the formation of a compound, but is probably caused by the presence of the 'eutectic alloy' in the mass. We are now repeating our experiments with synthetically prepared organic bodies of known constitution, and studying also the cooling curve of water.

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7. *On the More Exact Determination of the Densities of Crystals.*
By the Earl of Berkeley.

A comparison of the several values found by different observers for the density of one and the same crystallised salt shows variations amounting in some cases to 10 per cent. As the density is assumed to be a physical constant, independent of the manner in which the crystals have been produced, these variations are probably due to errors of experiment.

The chief sources of such errors are (1) imperfect measurement of temperature and volume, (2) occlusion of mother liquor, (3) adhesion of air, (4) hygroscopic nature of the salts.

In the paper are described the methods devised by the author for reducing the amount of these errors.

1. Two conical pyknometers, of about 7 c.c. capacity, with thermometer stoppers and calibrated capillary side tubes, were used. One served as a counterpoise, and was treated externally exactly like the other. They were repeatedly heated to 130° C., and allowed to cool, in order to bring the glass into a condition of molecular rest. For determining capacity the flask filled with water was placed in a desiccator, from which the air was exhausted till, on tapping, the water boiled. After it had thus been kept boiling for some time, the flask was removed, and the stopper inserted in a position and under a pressure which were observed. After the two pyknometers had been wiped dry they were placed on the balance pans, and when the temperature had become steady and the level of the liquid in the capillary had, in consequence of evaporation round the neck, fallen below the highest graduation, the weight, the level in the capillary, and the temperature were noted. The greatest difference between any two out of eight estimations of capacity thus made was 0·00029 c.c.

The liquid in which the crystals were weighed was carbon tetrachloride. Owing to the high coefficient of expansion of this liquid, special means, which are described, were devised for keeping constant the temperature of the balance case. The evaporation between the neck and the stopper was at the rate of about 0·0001 gram per minute.

2. To remove occluded mother liquor the crystals may be reduced to powder and then dried, the presumption being that the crystals will break across the cavities containing the mother liquor, and that the latter on evaporating will deposit crystals of the same kind. But the crushing process may produce change, as in the familiar case of mercuric iodide; and it is better to form small crystals in a solution kept at a constant temperature and constantly stirred. An apparatus was planned and constructed for this purpose.

3. To prevent adhesion of air, the pyknometer with the weighed crystals at bottom, together with a bulb holding a charge of carbon tetrachloride, were so

connected that, when the air had been exhausted from the flask, vapour from the boiling carbon tetrachloride took its place in the interstices of the crystals. Then, by tilting the vessel, the flask was filled with liquid tetrachloride. On removing the flask the stopper was inserted as before. Eleven determinations of the density of quartz show a maximum divergence of ·02 per cent.

4. To remove moisture retained on the surface of the crystals, a current of dry air was passed through the flask till on passing out it yielded no moisture to phosphorus pentoxide. The apparatus was then exhausted, and carbon-tetrachloride was admitted sufficient to cover the crystals. The flask was then filled up as before. Four determinations by this method of the density of K^2CO^3 show a maximum divergence of ·04 per cent.

8. *The Equivalent Replacement of Metals. By* Professor FRANK CLOWES, *D.Sc., Lond.*

It has long been known that when iron is immersed in a solution of cupric sulphate metallic copper is deposited, and an amount of iron passes into solution which is exactly able to combine with the sulphate radicle liberated from the cupric sulphate. The weights of copper and of iron which combine with the same weight of sulphate radicle have been determined by carrying out the process quantitatively. These weights are chemically equivalent to one another, for they are able to combine with the same weight of the acidulous radicle.

In the case just cited the chemical change appears, at ordinary temperature and with dilute cupric solution, to follow the simple course stated. But attempts to extend this direct method of ascertaining the relative equivalents of metals cease to be direct in certain cases, owing to the complicated nature of the reactions which occur.

My attention was drawn to such a complication in the case of the action of magnesium on cupric sulphate solution, and the nature of the reaction was then investigated by R. M. Caven, B.Sc., and myself. Commaille,[1] Kern,[2] and Vitali,[3] had drawn attention to the facts that during the action of magnesium on cupric sulphate solution cuprous oxide was deposited with the metallic copper, and hydrogen was evolved. These facts prove that the copper equivalent of magnesium cannot be obtained by simply weighing the magnesium which passes into solution and the deposit which was formed during the process. But we proceeded to make a fuller examination of the nature of the reaction, and to show that when it was quantitatively carried out the products enabled us to calculate the equivalents of magnesium and copper.

Having obtained practically pure materials, we proceeded to study the reactions when the conditions were varied by employing hot or cold and strong or weak cupric sulphate solutions. We were met with the initial difficulty that cupric sulphate solution deposits a basic salt when it is boiled: this salt we separated and found to correspond in composition and properties to the formula $4CuSO_4.7Cu(OH)_2.H_2O$. Pickering had separated a similar salt, to which he attributed the formula $6CuO.2SO_3.5H_2O$. Owing to the deposition of this salt complicating the products, we avoided actual ebullition in our experiments.

The action is most simple when the magnesium is immersed in a hot strong solution of cupric sulphate. Hydrogen is briskly evolved, a chocolate-coloured deposit forms, and green flakes are produced which disappear before the reaction is completed. Treatment of the brown deposit with dilute hydrochloric acid yields colourless cuprous chloride solution and a small residue of metallic copper. The hydrogen evolved was collected and measured, the metallic copper was weighed directly, and the amount of cuprous oxide was determined by dissolving it in hydrochloric acid and determining the amount of cuprous chloride thus formed by

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[1] *Comptes Rendus*, lxiii. p. 556.

[2] *Chem. News*, xxxiii. p. 236.

[3] *Journ. Chem. Soc.*, lxx. p. 419.

titrating it with standard permanganate solution in the presence of a sufficient amount of magnesium sulphate. As a result of four experiments, the average sum of the magnesium equivalents of the cuprous oxide, the copper, and the hydrogen amounted to 0·102 gram, and the average weight of magnesium used was 0·105 gram. The ratios of the weights of hydrogen, copper, and cuprous oxide produced were constant only when the conditions of the experiment were precisely similar.

When the hot cupric sulphate is dilute, or when it is employed at ordinary temperature, the reaction pursues at first a similar course, but it soon becomes very considerably delayed by the formation of a green basic cupric salt, intermingled with colourless basic magnesium salt. Thus, the reaction on the magnesium was usually complete in ten minutes in an excess of a hot, strong solution of cupric sulphate; but in weak and cold solutions it often extended over several days, and even a week.

The percentage of hydrogen, compared with that which is equivalent to the magnesium employed, was in the case of the hot solution 34·7; with the cold solution, it was 41·5 with weak solution, and 30·6 with saturated solution.

Various explanations have been given of the causes which lead to deposition of cuprous oxide and to evolution of hydrogen. It has been suggested that the change is due to impurity in the copper salt; this we have disproved by using a salt purified by frequent recrystallisation, and yielding 25·23 per cent. of copper (theory = 25·39); we have also proved the purity of the magnesium employed. Divers suggests that the evolution of hydrogen is due to the action of the magnesium upon free sulphuric acid, which has been formed by hydrolysis of the cupric salt. This seems to us to be an insufficient explanation of the rapidity with which hydrogen is evolved. Cold cupric sulphate solution was found to give no acid reaction with methyl-orange, although it is faintly acid to litmus paper. Yet such a solution gives an immediate evolution of hydrogen when magnesium is immersed in it, the evolution of the gas being very rapid in a hot and strong solution. After carefully studying the change, we are inclined to attribute the evolution of hydrogen in small degree to the presence of free sulphuric acid formed by hydrolysis in cold solution, and in greater degree to the same cause in hot solution. This involves the formation and separation of basic salt. This reaction, however, does not account for all the hydrogen evolved, and one of us will be prepared before long to advance a further explanation to account for this. Divers further suggests that cuprous sulphate is formed and almost immediately converted by the action of the basic cupric salt into cuprous oxide; this theory we also find to be untenable.

The immediate separation of cuprous oxide and evolution of hydrogen, without formation of basic salt, which occurs at the commencement of the reaction, may be represented by the equation:

$$2Mg + 2CuSO_4 + H_2O = 2MgSO_4 + Cu_2O + H_2.$$

The action of the magnesium-zinc couple has been proved to be too slow to explain the rapid escape of hydrogen, and if this were the origin of the hydrogen, its escape would not immediately follow the immersion of the magnesium.

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9. *A Note on Alkaline Chlorates and Sulphates of Heavy Metals.*
By W. R. Hodgkinson *and* A. H. Coote.

Many solid sulphates, whether containing water of crystallisation or anhydrous, when mixed and gently heated with potassium or sodium chlorate give off chlorine gas in addition to oxygen. In many cases the evolution of the chlorine seems to precede that of the oxygen. With sulphates containing crystallisation water chlorine is evolved with it, as steam, on heating. Mixtures also of anhydrous sulphates, as those of copper and manganese with chlorates, give off a mixture of oxygen and chlorine at temperatures very little above 100° C.

The theoretical equations

$$(1)\ MSO_4 + 2KClO_3 = K_2SO_4 + MCl_2O_6 \text{ and } (2)\ MCl_2O_6 = MCl_2 + 3O_2,$$

where M is a divalent or a polyvalent metal, scarcely hold at all. In the cases, lead, silver, mercury, where it seemed most likely to hold, it certainly does not; for the dry sulphates of these metals mixed in fine powder with potassium chlorate, and very gently heated—to about 120°—give off chlorine very briskly, and the residue is a mixture of potassium sulphate and chloride, and the oxide and chloride of the other metal. In the case of lead, the peroxide is formed.

In a few cases this decomposition takes place with solutions of the salts. Manganese sulphate and alkaline chlorate solution becomes brown after boiling a few minutes.

We have mixed different sulphates and potassium chlorate in equivalent quantities, and endeavoured to ascertain the relation between the oxygen and chlorine evolved; but even with careful heating the results have not been very concordant.

The sulphates of the following metals have been tried:—

Zn, Ni, Mn, Mg, Fe, Cu, with and without crystallisation water. Ag, Hg, Pb, anhydrous. Several alums both with and without water.

It may be here noted that many metallic chlorates decompose when their solutions are evaporated, even at the ordinary temperature and under reduced pressure. This is notably the case with manganese and ferric chlorates.

The sulphates employed were carefully purified, and contained no free acid.

SATURDAY, SEPTEMBER 10.

The Section did not meet.

MONDAY, SEPTEMBER 12.

A Joint Discussion with Section A on the recent Eclipse Expeditions was held.

The following Reports and Papers were read:—

1. *Report on the Teaching of Natural Science in Elementary Schools.*

See Reports, p. 433.

2. *Juvenile Research. By* Professor H. E. ARMSTRONG, *F.R.S.*

3. *Green Cobaltic Compounds. The Result of Oxidising Cobaltous Salts in presence of Organic Salts of the Alkali Metals. By* R. G. DURRANT, *M.A., F.C.S.*

Hydrogen peroxide and other oxidising agents are capable of forming green solutions with cobaltous salts in presence of fairly concentrated solutions of potassium bicarbonate, oxalate, glycollate, acetate, citrate, malate, lactate, and succinate. Potassium may be replaced by the other alkali metals, and in some cases by ammonium, barium, strontium, or calcium.

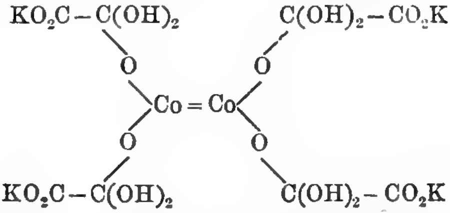
The cobalt in the green bicarbonate solutions has been shown to be present in the cobaltic state by volumetric experiments involving, (*a*) the maximum depth of green, (*b*) the non-appearance of a precipitate, (*c*) the estimation of iodine liberated.

A potassium salt, formed by the action of hydrogen peroxide on cobaltous oxalate dissolved in potassium oxalate, has been isolated and analysed ; the formula appears to be $K_4Co_2(C_2O_4)._4 4H_2O$.

This body, unlike Kehrmann's $K_6Co_2(C_2O_4)_6 6H_2O$, exhibits no dichroism. It occurs in green, transparent, microscopic crystals, belonging in all probability to the rhombohedral system.

The salt is very stable; its solution in water gives no precipitate with dilute calcium chloride, while concentrated calcium chloride yields minute green, needle-shaped crystals of the corresponding calcium salt.

The properties of the potassium salt in regard to its behaviour when heated, solubility, lowering of freezing-point, action of acids, alkalis, reducing and oxidising agents, have been studied, from which it would appear that a structural formula



is probable, the body having lost a previously acquired atom of oxygen between the cobalt atoms.

The absorption spectrum of the aqueous solution exhibits two bright bands—one in the red with centre near the C line; the other in the green with centre approximately $\lambda = 5150$. The absorption spectra of other cobaltous and cobaltic solutions have been studied; that of the bicarbonate green exhibits no red band, but gives a single bright band in the green with centre approximately $\lambda = 5365$. There appears to be a *reversal* of the band in the green when cobaltous solutions are oxidised to form these green compounds.

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4. *Analysis of Dorsetshire Soils.* *By* C. M. Luxmoore, *D.Sc.*, *F.I.C.*

The investigation of the Dorsetshire soils, which has recently been commenced at Reading College, is not forward enough to enable us to publish any results at present, but an account of the methods that are adopted will perhaps be of interest.

As the object of the work is to obtain a general knowledge of the soils of the county, the samples are taken from land lying on the various geological formations that occur, and so selected as to be, in the opinion of local agriculturists, typical of a more or less considerable area of land in the neighbourhood. Three samples of the soil of each selected field, usually along a diagonal line, are taken much in the manner directed by the Royal Agricultural Society, using, however, boxes 6 inches by 6 inches in area and 18 inches deep, and made so that one side can be readily removed, showing the soil in section. When the boxes are opened at the laboratory the soil is separated from the subsoil, a division being made at the arbitrary depth of 9 inches, and also at any other line where a definite change in the character of the soil is manifest. The larger stones, if any, having been removed, the sample is carefully divided so as to reduce it to about one kilogramme; the smaller stones and gravel are then separated by sifting under water, and the fine earth passing a sieve $\frac{1}{12}$-inch mesh is dried at a moderate temperature in a copper oven. If the three samples taken from a field appear fairly similar, a mixture of them is made for analysis, but the original samples are preserved for reference. The chemical analysis of these mixed samples offers at present nothing worthy of special notice; it includes, of course, in addition to the usual complete analysis of the portion soluble in hydrochloric acid, a determination of the available potash and phosphoric acid, according to Dyer's method. A series of mechanical analyses of the soils according to a slight modification of Osborne's method of subsidence has also been commenced. This enables one to determine the percentage of soil consisting of particles within certain limits of size, and thus to obtain a rough approximation to the total surface area of the soil particles. No doubt the attraction of the soil for moisture is dependent very largely upon the surface area of the particles; though certain preliminary experiments, which the author was enabled—through the kindness of Sir Henry Gilbert—to carry out at Rothamsted some time ago on the soil of the Broadbalk field, lead him to believe that the relation is not so simple as might at first sight be expected.

The selection of suitable fields and the collection of samples are carried out by the agricultural staff of Reading College, and the author's colleagues take the opportunity of making notes at the time of the various physical features of the land, &c. With a view to obtaining a thoroughly general knowledge of the soils of Dorsetshire, it is proposed to sample and analyse one hundred of them, in the manner indicated, during the course of the next five years. It is important to mention that this investigation is being carried out under the auspices of the Dorsetshire County Council, who have made a grant towards the necessary expenses.

5. *Report on the Carbohydrates of Cereal Straws.*—See Reports, p. 293.

6. *Interim Report on the Promotion of Agriculture.*—See Reports, p. 312.

TUESDAY, SEPTEMBER 13.

The following Papers and Reports were read:—

1. *Recent Advances in the Leather Trade.* *By* J. GORDON PARKER, *Ph.D.*

A new and important tanning material, containing upwards of 30 per cent. of tannin, is canaigre. To light leathers, tannage with it gives suppleness and mildness. Quebracho is increasingly used. The most important change of method, however, in the manufacture of leather is the now almost universal employment of extracts, principally those of oakwood and chestnut—a method which is the indirect outcome of chemical science. Up to a comparatively recent date there was no known chemical means by which one extract could be detected from the other. The tanner's chemist can, however, now determine between them, and also detect their adulterants, quebracho, myrabolams, cutch, divi-divi, algarobilla, &c.

The extended use of extracts has brought about improved methods of estimating the tanning values of materials used in tanning. The considerable differences in the results of analyses of one and the same sample by different chemists culminated in the holding in London of a conference, and the formation at that conference of the International Association of Leather Trades' Chemists; an Association from which much may be expected, particularly in the direction of the adoption of standard methods for the analysis of tanning materials.

In regard to the fermentation that takes place in tan liquors, chemistry had already afforded considerable enlightenment. One no longer talks of the waste of tannic acid and the formation of gallic acid; but the presence of acetic, lactic, and propionic acids is detected, their percentage easily estimated, and in every well-regulated tanyard their value and uses are thoroughly appreciated. The formation of mould is checked, and the action of certain antiseptics thoroughly understood.

The bateing and puering of skins by means of dog and hen excrement is a standing disgrace to the leather trade. Many substances in substitution for excrement have been tried, but not with much success. The opinion is generally held that bacteriological action is necessary in the bateing and puering process, and Mr.

J. T. Wood and others have succeeded in isolating over twenty different kinds of bacteria from the puer and bate referred to, and in culturing the bacteria. Within the last few weeks tubes containing cultures of the bacteria which are suitable for bateing and puering purposes have, I believe, been put upon the market in Germany. This is a form of applying the excrement bate that makes it far less objectionable than heretofore.

Mr. Wood has also applied bacteriological investigation to the bran drench, and he has shown that for some leathers acetic and lactic acids may be substituted for the fermenting bran.

The rush after quick tanning processes is somewhat reactionary. No great success has been achieved by the various drum processes, and no leather has been made by any of them that will serve other than second-class work. Leather produced by the so-called electric process is being worked successfully in Sweden, and the leather which is tanned in from eight to twelve weeks is to all appearance satisfactory; it has not been commercially tried in England. There is most probably what may be regarded as a rational limit of time for the conversion of hide into leather, and it is doubtful whether the time that up to now has been regarded as proper in such conversion will ever be very greatly reduced, as there is in tanning more than simple chemical combination of tannin with hide substance.

In the extraction of tanning materials in the tanyard, English tanners are far behind those of America and the Continent. A large amount of available tannin is often wasted by cold extraction. Most of the large tanyards on the Continent extract with warm water in closed vats, some even extracting under pressure. Analyses of over 300 samples of waste spent tan from over forty tanyards in Great Britain have shown an average of over 9 per cent. of available tannic acid. Supposing with valonia, costing 12*l.* per ton, and containing 36 per cent. of tannin, 5 per cent. to be thus wasted, a loss is incurred of 1*l.* 13*s.* 4*d.* per ton; and valonia is only one of the materials used in this country.

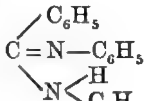
Investigation in the case of oak bark shows 61 per cent. of tannin extracted with cold water, and 95 per cent. with water at 60° C. Valonia extracted cold gives over 70 per cent. of tannin; at 60° C. gives off the whole of it. Even with hemlock, containing only about 16 per cent. of tannin, the Americans find warm extraction pay, and the Germans years ago adopted the method. The fear of darker colour in leather arising from the use of warm extracts is much exaggerated.

Chrome leather tannage has emanated from the chemist's laboratory, and leather is chromo-tanned by a two-bath process and by a one-bath process. The leather tanned by either method, for it is leather, has many advantages over vegetable-tanned leather. It is more elastic, more waterproof, and lighter and softer for foot-wear, except as to soles, for which its water-resisting quality makes it too slippery. Millions of dozens of skins are chromed weekly in America.

Owing to the labours of the late Professor von Schroeder, it is possible now to determine at any period during the tanning process what amount of tannin a hide has absorbed, and to Professor Proctor, of Leeds, we owe our present system of analysis. As to the future, a great advance in our knowledge may be expected from the several tanning schools and research laboratories that have come into existence, but there is still a marked need of more research and of specially trained chemists with a thorough knowledge of tanning.

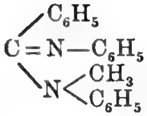
2. *Diamidated Aromatic Amidines, a New Class of Colouring Matters. By* E. Noelting, *Professor of Chemistry, College of Chemistry, Mulhouse.*

The benzenyl-di-phenyl-amidine,



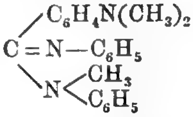
$$C_6H_5-C(=N-C_6H_5)-N\begin{matrix}H\\C_6H_5\end{matrix}$$

and its methylated derivative,



are white substances, having no colouring power at all.

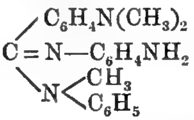
If we introduce in the latter one amido-group, or better, a di-methylated amido-group, $N(CH_3)_2$, we obtain a slightly yellowish substance



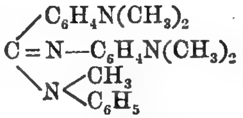
dyeing wool, silk, and cotton previously mordanted with tannin in light yellowish shades.

If another amido-group or di-methylated amido-group is introduced, we obtain a real, strong colouring matter, dyeing the above-named fibres in bright yellow.

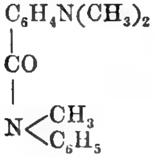
These substances



and

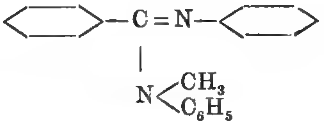


may be easily prepared by acting on dimethyl-amido-benzo-methyl-anilide

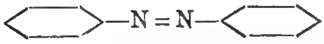


with para-phenylene-diamine or dimethyl-para-phenylene-diamine in the presence of oxychloride of phosphorus.

Benzenyl-diphenyl-methyl-amidine



may therefore be considered as a chromogen, similar to azo-benzene



Both, by the introduction of amido-groups, become real dye-stuffs, but whilst azo-benzene itself is coloured, the amidine is colourless in itself, like anthraquinone and other similar chromogens.

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3. *The Oxidation of Glycerol in presence of Ferrous Iron.* *By* HENRY J. HORSTMAN FENTON, *M.A., and* HENRY JACKSON, *B.A., B.Sc. Lond.*

The peculiar influence which ferrous iron exercises upon the oxidation of tartaric acid, and some other hydroxy-acids, which has been pointed out by one of the authors in several previous communications, is now being investigated as regards various classes of hydroxy-compounds. Mr. C. F. Cross, with the consent of the authors, has subsequently applied this reaction to his studies on certain carbohydrates, and Dr. Morrell is also making important investigations on the same subject. The authors are at present engaged in studying the *polyhydric alcohols,* and the present communication deals with the results obtained when glycerol is oxidized by hydrogen dioxide in presence of iron. Practically no result is obtained in the absence of ferrous iron, but, in its presence, an energetic reaction sets in, with the production of a liquid which powerfully reduces Fehling's solution in the cold, and which, with phenyl hydrazine, gives an abundant yield of glycerosazone, $C_{15}H_{16}N_4O$. The oxidation-product contains therefore either dihydroxy-acetone, glyceraldehyde, or a mixture of both of these substances ['glycerose'], and is now being examined with a view of isolation.

4. *Action of Hydrogen Peroxide on Carbohydrates in the Presence of Iron Salts. By* R. S. MORRELL, *M.A., Ph.D., and* J. M. CROFTS, *B.A., B.Sc.*

Cross, Bevan, and Smith[1] have shown that hydrogen peroxide acts as a mild oxidising agent on glucose in the presence of ferrous sulphate, giving acids, formic, acetic, and probably tartronic, and a substance which reduces Fehling's solution in the cold, and yields with phenyl-hydrazine in the cold a mixture of osazones.

The action of hydrogen peroxide in the presence of ferrous sulphate on organic acids has furnished important results in the case of tartaric acid, and the method employed by Cross, Bevan, and Smith is on the lines suggested by Fenton.[2]

We have been able to identify the substance, which reduces Fehling's solution in the cold and reacts so readily with phenyl-hydrazine, as glucoson.

We have prepared from the solution methyl-phenyl-glucosazon, and verified the property that this oxyglucose has of reacting easily with organic bases, *e.g.* (*o*) tolyldiamine. The glucoson resists the action of ferments, as was found to be the case by Fischer.[3]

The action of the hydrogen peroxide in the presence of iron salts is to oxidise the (CHOH) group next to the CHO group in glucose, forming $CHO.CO(CHOH)_3 CH_2OH$. With levulose and galactose a similar oxidation probably takes place. The investigation of these substances is in progress. In these two cases we expect to obtain (*a*) from levulose $CH_2OH.CO.CO(CHOH)_2CH_2OH$; (*b*) from galactose $CHO.CO(CHOH)_3CH_2OH$ (galactoson).

5. *An Experiment illustrating the Effect on the Acetylene Flame of varying Proportions of Carbon Dioxide in the Gas. By* Professor J. EMERSON REYNOLDS.

On a 10-*Candle Lamp to be used as a Standard of Light.*
By A. G. VERNON HARCOURT, *F.R.S.*

In previous years the author has made several communications to Sections A and B on standard lights. As weight is expressed in grains and length in feet, but a definite piece of brass or platinum is used to represent the grain, and a rule of definite length to represent the foot; so light is expressed in candles, but some more constant light than a candle-flame is needed to represent the candle. A small air-gas flame, first described to this Section in 1878, has been thus used in inquiries into the standard of light on several occasions since that date. The illuminative value of coal gas has commonly been estimated by comparing the distances at which the light of two candles and that of a standard Argand, consuming 5 cubic feet of gas per hour and giving a light of about 16 candles, illuminated equally the surface on which they fell. In clear air and with careful measurement of the smaller distance a comparison between a light of 16 candles

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[1] *C. S. J.* 1898, 73, 463.

[2] *C. S. J.* 1894, 65, 899; *C. S. J.* 1896, 69, 546.

[3] *Ber.* vol. xxii. p. 89.

and the light of two or even of one candle can be accurately made. But a material error is less likely to occur where the atmosphere may be foggy, and in a number of routine observations, if the two lights compared are more nearly equal For this reason in technical photometry it is better to make the standard of comparison a light of 10 or 16 candles. An actual cluster of so many candles would give a much more constant light than two candles, but its use on a photometer presents obvious and insuperable difficulties. Hence the need of a large but compact standard flame.

After many trials of Argand lamps with wicks and chimneys, the author concluded that the glass chimney was a source of variation, and that if possible an Argand lamp without a chimney must be produced. The result of many trials to produce a lamp of the right kind, and many adjustments, first large, then small, to obtain from such a lamp a constant light, and a light of exactly 10 candles, has been the lamp which is now before the Section.

The burner is supplied with a mixture of air and gaseous pentane from a reservoir carried on a bracket at the top of the lamp. As this mixture falls down the siphon connecting the two, fresh air enters the reservoir, which is provided with cross partitions causing the air to travel backwards and forwards over the surface of the pentane, and to mix with a proportion of pentane vapour, always large, though varying in amount with the external temperature. The variation in the proportion of pentane thus occurring does not affect the output of light under the other conditions about to be described. A casing round the burner with a conical top steadies the flame, the upper part of which is drawn together into a long brass chimney which cuts off the light of this part of the flame. Round the chimney is an outer tube, open below and connected above with a longer tube, which descends and is connected below with the central chamber of the burner. The longer tube is kept cool by having attached to it the bracket carrying the reservoir in which the pentane evaporates, and also a triangle of blackened copper which supports the bracket. Thus an air-current is produced, ascending in the heated and descending in the cooler tube, which issues through the middle of the Argand burner.

A steady flame of a height between 60 and 70 mm. is thus formed, giving a total light of rather more than 10 candles. By setting the tube which receives the top of the flame at a height of 47 mm., the light shed horizontally is reduced to exactly 10 candles. The total height of the flame can be observed through a small talc window in the side of the chimney, and regulated by means of a tap on the outlet of the reservoir. A variation of a centimetre in the height of the flame, or of a millimetre either way in setting the height of the chimney above the burner, makes no measurable difference in the light emitted.

As the lamp is tall and its centre of gravity rather high, and as an upset would cause a spilling of pentane which might be dangerous, a firm support is required. A tripod, which for levelling and stability is best, has the disadvantage that, unless the branches are very long, it offers a weak resistance to an upsetting force in three directions. The stand of this lamp has been strengthened in these three directions by being provided with three additional branches, whose screws are turned up so as not to touch the table till the lamp resting on the other three branches has been set upright. The screws of the three supplementary branches, which are made to turn very easily, are then turned down in succession till a slight resistance shows that each is just touching the table.

A number of comparisons have been made of four of these lamps one with another, and between the lamps and the 1-candle standard. The results show that all the lamps give the same amount of light, and that this light is exactly ten times that of the 1-candle standard.

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7. *On a Convenient Form of Drying Tube.*

By A. G. VERNON HARCOURT, *F.R.S.*

A common method of drying gases is to pass them through a wash-bottle containing sulphuric acid, and then through a U-tube filled with fragments of pumice moistened with the same liquid. The number of corks and connections in this arrangement increases the chance of leakage. The U-tube must be supported in an upright position both when in use and afterwards, that the acid may not come in contact with the corks; if too much acid is poured in, the bend becomes blocked by a plug of liquid; there is no means of telling when the acid has become less efficient by dilution; nor is it easy to recharge the tube with fresh acid.

The form of drying tube shown avoids these defects. It is at once wash-bottle and drying tube; it has one cork, and stands upright; the pumice can be well drenched with sulphuric acid, the excess draining down and filling the lower part, through which the gas bubbles, to a convenient height; dilution announces itself, and the acid is easily renewed. The shape is that of a Gay-Lussac burette, with a constriction about 2 inches from the bottom. A piece of pumice, large enough to block the constriction, is first dropped in, and the tube is filled to near the top with small fragments of pumice. In charging with acid care is taken not to wet the upper part of the tube; next day the level of the acid in the lower part of the tube is marked with a strip of gummed paper. The small side tube which enters the large tube near the bottom is the inlet for gas; when the moisture absorbed has raised the level of the acid about 2 mm. above the mark the acid in the lower part is poured off through the small tube, and fresh acid is poured in through the pumice. The inlet and outlet tubes are made of the same height, so that a series of similar drying tubes may readily be joined together.

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8. *Standards of Purity for Sewage Effluents.*[1] *By* Dr. S. Rideal.

The author discussed the 'Standards of Purity for Sewage Effluents' which local authorities have hitherto had in mind in deciding as to whether they should be permitted to be discharged into a river or not. It was pointed out that the majority of these standards are arbitrary and artificial. The 'Oxygen consumed' and 'Incubation' tests, lately in dispute at Manchester, bacterial and chemical figures, and the 'Fish test' were passed in review. But since the *nitrogen* is significant of the more dangerous forms of pollution, a calculation of the proportion between its oxidised forms, which are harmless, and the unoxidised, which are liable to occasion smells and to be otherwise deleterious, will denote the extent to which an effluent has been purified. The figure obtained, termed the 'percentage of purification,' ranges from *none* for raw sewage to 97·6 for a deep well in chalk. Moreover, as several observers have proved, the oxygen of the nitrate and nitrites is in an 'available' form, and is capable, with the help of bacteria, of supplementing the free dissolved oxygen of river water in destroying the remaining organic matter. From these considerations a formula is deduced which embodies all the natural data for the conditions of discharge of an effluent into a stream, including the flow and aëration of the latter, and the volume, oxygen required, and 'available oxygen' of the effluent. The result is a 'factor of safety,' C, which must never be below unity. The application of the formula shows that the Thames, with $C = 1{\cdot}08$, has so narrow a margin that it often has had to be supplemented, especially in warm weather, by the addition of oxidising agents, while the Exe, on the other hand, with $C = 7{\cdot}9$, has a large margin for natural purification.

It is concluded that 'an effluent which has been properly prepared, and is in an active state of wholesome bacterial change, under the above conditions of free and potential oxygen, if clear and nearly free from odour, may be safely discharged into any river of moderate volume.'

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9. *Action of Ammonia on Gun-cotton.* *By* W. R. Hodgkinson *and* Captain Owen, *R.A.*, *Artillery College, Woolwich.*

Gun-cotton that has been thoroughly washed with alcohol and ether ignites or explodes when heated to between 180° and 185°. Analysis of such gun-cotton gives figures agreeing very closely indeed with those required by a cellulose tri-nitrate.

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[1] Printed *in extenso* in *Sanitary Record*, xxii. 490.

Some time ago we made a number of experiments to ascertain whether contact with other gases than air would influence this igniting point, and also whether any or what effect would be produced on gun-cotton when exposed at about 100° to the following gases:—Carbon dioxide, carbon monoxide, hydrogen, sulphur dioxide, nitrous and nitric oxides, chlorine, hydrogen chloride, bromine, ammonia.

None of these gases was specially purified, but they were dried very thoroughly.

The carefully dried gun-cotton, in fine powder, was exposed to a current of the gases in a tube. The tube was provided with a jacket through which steam or alcohol vapour, &c., could be driven, so as to obtain approximately definite temperatures.

With the exception of ammonia, not one of these gases above named had any effect at temperatures below 100°.

With ammonia the first indication of an action was the ignition, and sometimes detonation, of the gun-cotton at about the temperature of boiling alcohol. The gun-cotton became yellow or brown just before exploding.

To ascertain the temperature of firing more nearly, the cotton was placed in a U-tube heated externally by a water bath. Some samples, fine powder, fired at 76° (temperature of water bath). Others as high as 80° or 82°. Pulped gun-cotton fired at the lowest temperatures.

It was noticed that when the current of ammonia was very slight, red fumes and a white cloud formed in the tube just before firing.

As this indicated a possible oxidation of the ammonia at the expense of the NO_3 of the gun-cotton, some experiments were conducted in a similar manner, but at temperatures not exceeding 20°.

No change was visible until the ammonia had passed over the cotton for some hours, and then only a slight yellow colouration.

On washing this yellow product with water, a solution was obtained containing a considerable quantity of nitrite.

Fresh gun-cotton of the same make gave but the slightest traces of nitrous acid, even when boiled with water.

All alkaline solutions, boiled on gun-cotton, give strong reactions for nitrites. The solutions are generally yellow.

Some gun-cotton was now spread out under a bell glass and ammonia gas steadily introduced. After a few days moisture was observed condensing on the interior surfaces of the bell glass, so the arrangement was simplified and the gun-cotton supported a few inches above some strong ammonia solution under a large bell glass. It was allowed to stand for some weeks in a cool place. The cotton gradually became quite brown, and at the end of a month partially liquefied into a brown jelly.

Exposure to light was found to very materially shorten the time necessary to get this brown stage.

The substance was tested from time to time for nitrites. The amount appeared to increase up to the liquefying stage and then diminish.

After six weeks' exposure to the damp ammonia atmosphere the mass was placed over sulphuric acid in a desiccator and a good vacuum maintained for three weeks. The mass swelled up and dried to a brown, porous, and friable body, without a sign of the original cellulose structure. Some ammonia was retained, and was not entirely removed by heating for several days in a current of dried air.

The brown product is almost completely soluble in water and in alkaline solutions, but scarcely at all in alcohol or ether and very slightly in acetone. Strong alkalies evolve ammonia.

Strong sulphuric acid causes an effervescence, and SO_2 is evolved. Much carbonisation takes place.

Nitric acid (cold, strong) dissolves it quietly, and on dilution with water there is no precipitate.

When heated in a dry state ammonia is first given off. It then explodes feebly, producing red fumes and leaving much carbon.

Acetyl and benzoyl chlorides act upon it very energetically, and a light yellow resin is left on evaporation.

Acetic acid dissolves the brown substance, carbon dioxide being evolved. The product on evaporation leaves a clear, glassy substance.

In some later experiments the end of the ammonia action was considered to be reached when the brown mass ceased to gain weight after exposing to dry ammonia gas (nearly three months).

Nitrogen determinations in this sample gave 21·2 per cent. and 21·46 per cent. Some earlier samples contained only about 20 per cent.

The carbon and hydrogen determinations are very unsatisfactory. Mean of several carbon 21·5, hydrogen 3·5. They show a slight loss of carbon and gain of hydrogen compared to the original gun-cotton. There is evidently an increase of about 7 per cent. in the nitrogen. Possibly a further study of the acetyl compound of this product may throw some light on the reaction.

The nitrates from starch, mannitol, sugars, are also affected in a similar manner by ammonia. Glycerol nitrate (nitro-glycerine) is not affected either by gaseous ammonia at 100° or by standing under strong ammonia solution for twelve months.

Methyl and ethyl, amine, and aniline act upon gun-cotton in a similar but less energetic manner than ammonia.

The subject is being continued.

10. *On Nitroso-pinene.* *By* J. A. SMYTHE.

By the reduction of nitroso-pinene ($C_{10}H_{15}NO$) with zinc in acetic acid solution, there is formed, besides pinylamine, a new isomeric camphor ($C_{10}H_{16}O$) called pinocamphone.

The boiling-point of pinocamphone is 211°–213°. Pinocamphone oxime melts at 86°–87°. Pinocamphone semicarbazone melts at 208°. Reduction of ketone with sodium gives an isomeric borneol, $C_{10}H_{18}O$ (pinocampheole), which boils at 218°–219°. The phenylurethane of pinocampheole melts at 98°. Pinocampheole and zinc chloride yield cymene. Pinocamphone is the first synthetic camphor, the oxime of which in treatment with dehydrating agents gives a nitrile. Oxidation of pinocamphone yields a mixture of fatty acids. The reduction of bromnitroso-pinene ($C_{10}H_{15}NOBr_2$) with zinc in acetic acid solution yields, not pinylamine and pinocamphone, but an unknown base and bihydrocarvone.

These results can only be satisfactorily explained on the assumption of Wagner's formula for pinene.

11. *The Constitution of Oxycannabin.* *By* T. B. WOOD, *M.A.*, W. T. N. SPIVEY, *M.A.*, *and* T. H. EASTERFIELD, *M.A.*, *Ph.D.*

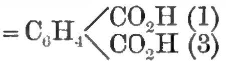
Oxycannabin is a yellowish-white crystalline compound obtained by Bolas and Francis in 1871 by the oxidation of pharmaceutical extract of hemp with nitric acid. It has hitherto possessed little interest, since it was not known from what naturally occurring compound the oxycannabin was derived, or what its chemical relationships were.

The authors have found that that portion of hemp resin which boils at about 400° C. contains two compounds; one of these yields a crystalline acetyl derivative, and has the formula $C_{21}H_{26}O_2$. Cold fuming nitric acid converts this into a crystalline trinitro compound $C_{21}H_{23}(NO_2)_3O_2$, which yields characteristic salts, and which, by the action of hot fuming nitric acid, yields 'Oxycannabin,' together with caproic, valeric, and butyric acids.

The formula ascribed by Bolas and Francis to oxycannabin was $C_{20}H_{22}N_2O_7$; in reality it has the formula $C_{11}H_{11}NO_4$, which has nearly the same percentage composition. It is a lactone, and yields salts of the type $C_{11}H_{12}NO_5M'$. Upon reduction it yields an amido-lactone $C_{11}H_{11}(NH_2)O_2$, from which, by Sandmeyer's reaction, a crystalline iodo-lactone, $C_{11}H_{11}IO_2$, has been obtained. The iodo-lactone, when treated in alkaline solution with sodium amalgam, is reduced to the parent cannabino-lactone, $C_{11}H_{12}O_2$, a colourless liquid boiling at 290° C.

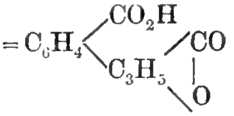
Cannabino-lactone, when oxidised with potassium permanganate, is converted almost quantitatively into cannabino-lactonic acid, $C_{11}H_{10}O_4$, which crystallises from water in magnificent colourless needles, melting at 203° C., and which by potash fusion under suitable conditions gives a quantitative yield of isophthalic acid. If, now, we trace the relationships backwards, we are forced to the following conclusions:—

Isophthalic acid = $C_8H_6O_4$



$$=C_6H_4\begin{cases}CO_2H\ (1)\\ CO_2H\ (3)\end{cases}$$

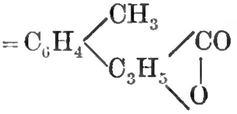
Cannabino-lactonic acid . = $C_{11}H_{10}O_4$



$$=C_6H_4\begin{cases}CO_2H\\ C_3H_5\begin{cases}CO\\ O\end{cases}\end{cases}$$

= *m*-Carboxy-phenyl-butyro-lactone.

Cannabino-lactone . . . = $C_{11}H_{12}O_2$



$$=C_6H_4\begin{cases}CH_3\\ C_3H_5\begin{cases}CO\\ O\end{cases}\end{cases}$$

= *m*-Tolyl-butyro-lactone.

Oxycannabin . = $C_{11}H_{11}(NO_2)O_2$ = Nitro-*m*-Tolyl-butyro-lactone.

= Nitro-cannabino-lactone.

There are three possible *m*-Tolyl-butyro-γ-lactones, none of which is at present known. Further research must show which of these is identical with cannabino-lactone, and also the position of the nitro group in oxycannabin.

12. *The Action of Certain Substances on the Undeveloped Photographic Image.* *By* C. H. BOTHAMLEY, *F.I.C., F.C.S.*

It has been known for some time to practical photographers that just as there are certain substances that have the power of 'fogging' or producing a developable image on photographic plates, so there are substances that have the power of destroying the latent image produced by the action of light. Several years ago a plate which the author had fully exposed on a landscape was wrapped in three or four thicknesses of tissue paper, and outside this some orange paper with printed matter on the outer surface, the whole being enclosed in a metal box with other plates. After some months the plate was developed, and it was found that on the negative there was an image of the printed matter on the outside of the paper, this image being much less opaque than the surrounding parts of the negative. It followed that the printer's ink had given off some vapour which had passed through the several thicknesses of paper, and destroyed the developable image produced by the action of light. Somewhat later it was found that in the case of several exposed plates that were left in the dark slides for some weeks the material composing the hinges of the slides had emitted some vapour that had undone the work done by light, the hinges being represented by almost transparent bands in the negatives. Abney showed long ago that hydrogen peroxide will destroy the image produced by light, and the author finds that the vapour of the peroxide has the same effect if allowed to act for sufficient time. It is probable, therefore, that effects such as those just described are due to hydrogen peroxide formed in the slow oxidation of the particular substance. Turpentine vapour, which produces hydrogen peroxide when oxidised by moist air, also completely destroys the developable image produced by light. Some evidence has been obtained that in the earliest stages of the action the reducing effect of hydrogen peroxide, as observed by Russell, is added to the effect produced by light, but with longer time the hydrogen peroxide destroys the developable image so produced. The general conclusion is that hydrogen peroxide, when it acts in small quantities or for a short time, acts as a reducer and produces a developable image on the photographic plate; but when it acts in a more concentrated form, or for a longer time, it acts as an oxidising agent and destroys the developable image.

Probably both the reducing and oxidising actions take place simultaneously, and the result at any given instant depends on their relative rates.

13. *Report on a New Series of Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 313.

14. *Report on Isomeric Naphthalene Derivatives.*—See Reports, p. 311.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—W. H. HUDLESTON, M.A., F.R.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

Introductory.—About this time last year British geologists were scattered over no inconsiderable portion of the northern hemisphere, partly in consequence of the International Geological Congress at St. Petersburg, and partly owing to the meeting of the British Association at Toronto. From the shores of the Pacific at Vancouver on the one hand, to the highlands of Armenia on the other, there were parties engaged in the investigation of some of the grandest physical features of the earth's surface.

The geologists in Canada were especially favoured in the matter of excursions. Everything on the American continent is so big that a considerable amount of locomotion is required to enable visitors to realise the more prominent facts. If there is no great variety of formation in Canada, yet the Alpha and Omega of the geological scale are there most fully represented, from the great Laurentian complex at the base to the amazing evidences of glacial action, in a country where it is possible to travel for a whole day without once quitting a glaciated surface. But Russia presented equal attractions, and in Finland almost identical conditions were observed—viz. glacial deposits on Archæan rocks. The great central plain of Russia, too, with its ample Mesozoic deposits often abounding in fossils, offered attractions which to some may have been stronger than the mineral riches of the Urals or the striking scenery of the Caucasus.

It seems almost incredible, even in this age of extraordinary locomotion, that scenes so wide apart were visited by British geologists last autumn. This year we are more domestic in our arrangements, and Section C finds its tent pitched once more on the classic banks of the Bristol Avon, and in that part of England which has no small claim to be regarded as the cradle of English geology. But we may go a step further. For if the strata observed by William Smith during the six years' cutting of the Somersetshire coal-canal imprinted their lessons on his receptive mind, it is also equally true that Devonshire, Cornwall, and West Somerset first attracted the attention of the 'Ordnance Geological Survey.' And thus it comes to pass that the region which lies between the Bristol Channel and the English Channel claims the respect of geologists in all parts of the world, not only as the birthplace of stratigraphical palæontology, but also as the original home of systematic geological survey.

The city of Bristol lies on the confines of this region, where it shades off north-westwards into the Palæozoics of Wales and north-eastwards into the Mesozoics of the Midland Counties. There are probably few districts which display an equal amount of variety within a limited circumference. The development of the various formations was excellently portrayed by Dr. Wright, when he occupied this chair twenty-three years ago—so well, indeed, that his address might serve as a text-book on the geology of the district. In the following year (1876) there appeared the Survey Memoir on the Geology of East Somerset and the Bristol Coal-fields by Mr. H. B. Woodward, who has since contributed important memoirs on the Jurassic rocks of Britain, which are so largely developed in Somerset and the adjacent counties. Since that date many papers also have appeared in various journals, and some of these, as might be expected, give new and perhaps more accurate interpretations of phenomena previously described. In addition to this, portions of the south-west of England have been geologically re-surveyed, and in some cases new maps have been published.

I would call especial attention to the Survey map on the scale of four miles to the inch, known as the 'Index-map,' which has recently been issued. Sheet 11 includes this particular district; but if a portion of sheet 14 is tacked on to its southern border we obtain a block of country about 120 miles square, which has not its equal for variety of geological formation in any part of the world within the same space. If Europe is to be regarded as presenting a geological epitome of our globe, and if Great Britain is an epitome of Europe, then, without doubt, this particular block of the south-west, which has Bath for its more exact centre, with a radius (say) of fifty miles, may be said to contain almost everything to be found on the geological scale, except the very oldest and the very youngest rocks; while east of the Severn and south of the Bristol Channel true Boulder clay is rare or absent.

It may be convenient to consider a few points which have arisen of late years in connection with the geology of portions of the district now under consideration.

Palæozoic.—If we omit the Silurian inlier at Tortworth, the geological history of the country, more immediately round Bristol, may be said to commence with the Old Red Sandstone, whose relations with the Devonian towards the south-west have always presented some difficulty. And this difficulty is accentuated by doubts as to the true Devonian sequence in West Somerset and North Devon. Ever since the days of Jukes that region has been fruitful in what I must continue to regard as heresy until the objectors have really established the points for which they are contending. The uncertainty is to be regretted, since it is through these beds of West Somerset that the system is to be made to fit in with the several members of the Old Red Sandstone.

There is a mystery underlying the great alluvial flats of Bridgewater which affects more than one formation; so much so that one cannot avoid asking why there should be Old Red Sandstone in the Mendips and Devonian in the Quantocks. The line which separates the Old Red Sandstone of South Wales and the Mendips from the West Somerset type of Devonian lies here concealed. I have already suggested[1] that, if we regard the Old Red Sandstone of South Wales as an inshore deposit over an area which was deluged with fresh water off the land, we can believe that further out to sea, in a south-westerly direction, the conditions were favourable for the development of a moderate amount of marine mollusca. This view not only does away with the necessity for a barrier, but it also, in a general sense, suggests a kind of gradation between the Old Red and Devonian deposits. Mr. Ussher, whose practical acquaintance with this region dates from a long period, stated a few years ago that, 'as far as Great Britain is concerned, the true connections of the Old Red Sandstone beds with their marine Devonian equivalents have yet to be carefully worked out on the ground.'[2] I am not aware that further progress has been made in this direction.

The Carboniferous Limestone of the Bristol area has attracted the attention of so many distinguished geologists that its palæontology and general features are tolerably familiar. Of late years we owe some interesting petrographic details to Mr. Wethered. The varying thickness of the Carboniferous Limestone and also of the Millstone Grit in this part of England is noteworthy. If we follow the Carboniferous Limestone in a south-westerly direction, across the mysterious

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[1] *Trans. Devonsh. Assoc.* vol. xxi. (1889), p. 45.

[2] 'Prospects of obtaining Coal by Boring South of the Mendips,' *Proc. Som. Nat. Soc.* vol. xxxvi. (1891), pt. 2, p. 104.

Bridgewater flats, a change is already noted in the case of the Cannington Park limestone, which was the subject of so much discussion in former years. Referring to this, Mr. Handel Cossham [1] was so sanguine as to believe that its identification with the Carboniferous Limestone would have the effect of extending the Bristol coal-field thirteen miles south of the Mendips. However this may be, all further traces of Carboniferous rocks fail at this point. After crossing the vale of Taunton, when next we meet with them in the Bampton district, the Culm-measure type, with its peculiar basal limestones, is already in full force.

In the new 'Index-map' the Culm-measures are placed at the base of the Carboniferous series—below the Carboniferous Limestone. It is no part of my purpose to attempt any precise correlation, but I would point out the somewhat singular circumstance that the change to Culm rock occurs only a few miles to the south-west of the line where, in the previous system, we have already seen that the Old Red Sandstone changes into the Devonian. This curious coincidence may be wholly accidental, or it may be the result of some physical feature now concealed by overlying formations.

Since 1895 a new light has been thrown on the Lower Culm-measures by the discovery of a well-marked horizon of Radiolarian rocks. One result of the important paper of Messrs. Hinde and Fox has been to alter materially our views as to the physical conditions accompanying the deposition of a portion of the Culm-measures. The palæontology leads the authors to conclude [2] that 'the Lower *Posidonomya*- and Waddon Barton Beds are the representatives and equivalents of the Carboniferous Limestone in other portions of the British Isles; not, however, in the at present generally understood sense that they are a shallow-water facies of the presumed deeper-water Carboniferous Limestones, but altogether the reverse, that they are the deep-water representatives of the shallower-formed calcareous deposits to the north of them. . . . The picture that we [Messrs. Hinde and Fox] can now draw of this period is that while the massive deposits of the Carboniferous Limestone—formed of the skeletons of calcareous organisms—were in the process of growth in the seas to the north [*i.e.* in the Mendip area and elsewhere] there existed to the south-west a deeper ocean in which silicious organisms predominated and formed these silicious Radiolarian rocks.'

This is probably a correct view of the case; but one cannot help wondering that the ocean currents and other causes did not effect a greater amount of commingling of the elements than seems to have taken place. As a practical result, this discovery of a Radiolarian horizon in the Culm-measures has been of service in enabling surveyors to discriminate between Devonian and Carboniferous in the very obscure area on the other side of Dartmoor. This, I ventured to predict, would be the case when the paper was read before the Geological Society.

The principal features of the Bristol coal-field are too well known to call for many remarks. It would seem that the Pennant rock was formerly regarded as Millstone Grit, until Mr. Handel Cossham, in 1864, pointed out the mistake.[3] Mr. Wethered gave a good description of the Pennant in his paper on the Fossil Flora of the Bristol Coal-field.[4] It might seem almost unnecessary to refer to the existence of such a well-known formation as the Pennant, but for the fact that in a recent scheme of the Carboniferous sequence in Somersetshire the Pennant rock was wholly omitted.

The interest now shifts from the almost continuous deposition of the later Palæozoics, in one great geosynclinal depression, to an entirely different class of phenomena. Nowhere, perhaps, are the effects of the post-Carboniferous interval better exhibited than in those parts of the South-west of England where Tertiary denudation has removed the Mesozoic deposits. Here we perceive some of the effects of the great foliations which terminated the Palæozoic epoch in this part

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[1] *Proc. Cottes. Club*, vol. viii. (1881–2) p. 20 *et seq.*

[2] *Quart. Journ. Geol. Soc.* vol. li. (1895), p. 662.

[3] Since the Address was read, I have found that what Mr. Cossham showed was that a small tract marked 'Millstone Grit' in the survey map at Kingswood, east of Bristol, belongs to the Pennant Grit (see *Geol. Mag.* ii. 110).

[4] *Proc. Cottes. Club*, vol. vii. (1878), p. 73.

of the world. The immense amount of marine denudation which characterises this stage is particularly obvious in the anticlinals, which were the first to suffer, as they came under the planing action of the sea.

Attention may be drawn to a peculiarity which has no doubt been observed by many persons who have studied a map of the Bristol and Somerset Coal-field. It will be seen that the strike of the Coal-measures is widely different on either side of a line which may be drawn through Mangotsfield to a point north of Bristol. The beds north of this line have for the most part a meridional strike, nearly parallel with the present Cotteswold escarpment; south of this line the strike is mainly east and west, though much curved in the neighbourhood of Radstock and the flanks of the Mendips. Of course, this is only part of an extensive change in the direction of flexure, much of which is still hidden under Mesozoic rocks. Mr. Ussher, in the paper previously quoted, tells us that the line of change of strike may be traced in the general mass of the Palæozoic rocks, from near Brecon in South Wales to the neighbourhood of Frome. This means that within the Bristol district two distinct systems of flexure must have impinged on each other in post-Carboniferous times. Have we not here, then, another instance of extraordinary change within the limits of our area? This time it is not a mere change in the nature of a deposit, like that of the Old Red Sandstone into the Devonian, or of the Carboniferous Limestone into the Culm-rock, but a change in the direction of the elevatory forces, which had made its mark on the structure of our island even at that early date.

At this point I ought to quit the Palæozoics; but there is just one subject of interest which claims a momentary attention—viz. the probability of finding workable coal east of the proved Somersetshire field. I avoid the question of coal south of the Mendips as being too speculative, on account of the chances of deterioration of the coal-measures in that direction. But, in view of the forthcoming meeting of the British Association at Dover, the question of finding coal to the eastward of Bath becomes a specially interesting subject for discussion. It is also a matter of some consequence whether the hidden basin or basins belong to the meridional or to the east and west system of flexures. The latter is most likely to be the case.[1] The vale of Pewsey has been mentioned as a suitable locality for boring along the line of the recognised axis.

But prospectors should bear in mind the warning of Ramsay, that the basins containing coal are but few in comparison with the number of basins throughout the Palæozoic rocks. No doubt the line indicated is more favourably situated for coal-exploration than the Eastern Counties; where, for instance, the Coal Boring and Development Company has lately gone into liquidation. The unsuitability of East Anglia as a field for coal-prospecting was insisted on in my second anniversary address to the Geological Society,[2] and the results seem to have been very much what might have been expected. If coal is to be found beneath the Secondary rocks the line of search should be carried through the counties of Kent, Surrey, Berkshire, and Wiltshire, though the three latter counties have hitherto been content to leave their underground riches unexplored. The Kent Coal Exploration Company is doing some good work with a reasonable chance of success; though if they wish to find coal sufficiently near the surface they had better adhere as much as possible to the line of the North Downs, since operations on the Sussex side are only too likely to be within the influence of the Kimmeridgian gulf, which was proved to exist at Battle (Netherfield). Mr. Etheridge, I hope, will have something to tell us as to the progress of the Kent Collieries Corporation, who now carry on the work at Dover.

Secondary or Mesozoic Rocks.—Commencing a totally different subject, I must now direct attention to the 'red beds,' and associated breccias so characteristic of

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[1] The boring at Burford, where coal was found at a depth of 1,100 feet, below a surface of Bathonian beds, at a point thirty-five miles E.N.E. of the extreme end of the Bristol coal-field at Wickwar, is not included in this category; since it must belong to the meridional system, and is altogether outside the prolongation of the axis of Artois.

[2] *Quart. Journ. Geol. Soc.* vol. l. (1894), p. 70.

Eastern Devonshire. These rest in complete discordance on the flanks of the Palæozoic highlands, and must be regarded as forming the base of the Secondary rocks of that district.

By the Geological Survey this series has hitherto been mapped as Trias, but in the new 'Index-map' they are coloured as Permian. There is no palæontological evidence which would connect them with the fossiliferous Permians, usually regarded as of Palæozoic age; but it has been evident for some time past that opinion was inclining to revert to the views of Murchison and the older geologists, more especially as to the position of the breccias so largely charged with volcanic rocks. The subject was dealt with by Sir A. Geikie in his address to the Geological Society, where he speaks of some of these rocks as presenting the closest resemblance to those of the Permian basins of Ayrshire and Nithsdale.[1]

One difficulty which presented itself to the Devonshire geologists in accepting the Permian age of the 'red beds' was, that the whole of the lower Secondary rocks appeared as an indivisible sequence, proved by its fossils to be of Keuper age at one end, and therefore inferentially of Keuper age at the other. Dr. Irving, however, considered that at the base of the Budleigh-Salterton pebble-bed there is a physical break of as much significance as that between the Permian and Trias of the Midlands. In the marls which underlie this pebble-bed he recognised a strong resemblance to the Permian marls of Warwickshire and Nottinghamshire; and Professor Hull, who had been studying the sections east of Exmouth about the same time, ultimately acceded to this view.[2] Its acceptance by the Survey thus throws all the Exmouth beds into the Permian; and that formation, according to the new reading, has an outcrop of some 35 miles from the shores of the English Channel to within 3 miles of Bridgewater Bay. The fertility of these red clays, loams, and marls has long been recognised by agriculturists, and it is not improbable that the abundance of contemporaneous volcanic material may in some measure have contributed to this result.

In conformity with the new mapping, the Budleigh-Salterton pebble-bed and its equivalents to the northwards are accepted as of Bunter age, and thus constitute the base of the Trias in the south-west. Like most pebble-beds, they are irregularly developed between the Permians and a strip of reddish sandstone (coloured as Keuper), which runs up from the mouth of the Otter to within a short distance of Bridgewater Bay. The materials of the pebble-beds are not of local origin, like so much of the breccia at the base of the Permian.[3] The general resemblance, both as regards scenery and composition, to the Bunter conglomerate of Cannock Chase has been pointed out by Professor Bonney, who seems prepared to endorse the recognition of the Budleigh-Salterton pebble-bed as a Bunter conglomerate. He was not impressed by any marked unconformity with the underlying series. To some extent we may accept this view, since, whatever may be the age of the Devonshire breccias and 'red beds,' they, in common with the Trias, must have been deposited under fairly similar physical conditions in a sort of Permo-Triassic lake basin.

The bulk of the Trias, including the Dolomitic Conglomerate of the Bristol district, is still regarded as of Keuper age, though it is now admitted, as insisted on by Mr. Sanders years ago, that the Dolomitic Conglomerate does not necessarily occupy the base of the Keuper, but is mainly a deposit of hill-talus, which has been incorporated with the finer deposits of the old Triassic lake as the several Palæozoic islands gradually became submerged. The great blocks which fell from the old cliffs were formerly regarded as proofs of glacial agency, and there are persons who still believe, more especially with respect to the Permian breccias, that such rocks are indicative of a glacial origin.

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[1] *Quart. Journ. Geol. Soc.* vol. xlviii. (1892), p. 161.

[2] *Cf.* Irving. *Quart. Journ. Geol. Soc.* vols. xliv. (1888), p. 149, xlviii. (1892), p. 68, and xlix. (1893), p. 79; and Hull, *op. cit.* vol. xlviii. (1892), p. 60.

[3] Northwards, *e.g.* at Burlescombe, Wiveliscombe, &c., the equivalent conglomerates are largely, if not entirely, of local origin (*cf.* Ussher, *Quart. Journ. Geol. Soc.* vols. xxxii. (1876), pp. 378, 382; and xxxiv. (1878), p. 461). Mr. H. B. Woodward confirms this. Note added October 1898.

In the 'Index-map' the Dolomitic Conglomerate and the Red Marl are thus included under the same symbol and colour. But this is also made to include the Rhætic—an arrangement which is hardly in accordance with the facts observed in the Bristol area. On a small-scale map so narrow an outcrop as that of the Rhætic could hardly be shown; yet its affinities are probably with the Lower Lias rather than with the Trias. The late Edward Wilson, whose recent death we all deplore, in his paper on the Rhætic rocks at Totterdown,[1] showed most clearly that the 'Tea-green marls,' which had previously been associated with the Rhætic, represent an upwards extension of the Red Marls of the Trias, in which the iron had suffered reduction; though there are indications of a change of conditions having set in before the deposition of the Rhætics. The black Rhætic shales which succeed usually have a sharp and well-defined base in a Bone-bed with quartz pebbles, &c., indicating a sudden change of physical conditions, though perhaps no marked unconformity. In the South Wales district the Rhætic limestones are said to be largely of organic origin, and, in addition to a Rhætic fauna, to abound in the lamellibranchs so plentiful in the lowest Lias limestones.[2]

The late Charles Moore always deplored the comparative poverty of the Trias in fossils. In his last communication to the Geological Society[3] he set himself to describe certain abnormal deposits about Bristol, and to institute a comparison with the region of the Mendips. He then suggested, on the faith of a sketch by Mr. Sanders, that the famous Durdham Down deposit, already inaccessible, might have been a fissure-deposit in the Carboniferous Limestone like those at Holwell. He also stated that at one time he had been inclined to regard the Reptilian deposit on Durdham Down as of Rhætic age; but the discovery of teeth of *Thecodontosaurus,* identical with those of Bristol, in a Keuper Marl deposit near Taunton, induced him to refer the Durdham Down deposit to the middle of the Upper Keuper. He had arrived at the conclusion that the same genera of vertebrata are found in the Keuper and Rhætic beds, though the species, with few exceptions, are quite distinct.

But it is with the Lias that the name of Charles Moore is most intimately associated. Time does not permit me to do more than allude to the wonderful collections of Rhætic and Liassic fossils made by him from the fissure-veins of the Carboniferous Limestone, or of the treasures which are stored in the Bath Museum. There never was a more enthusiastic palæontologist, and nothing pleased him better than to exhibit the fossilised stomach of an *Ichthyosaurus,* stained by the ink-bag of the cuttle-fish, on which it had been feeding, or some similar palæontological curiosity. Everyone here knows how deeply the West of England is indebted to Charles Moore for his unceasing researches, and I have been thus particular in alluding to them because it was under his auspices that I first became acquainted with the geology of this part of the country just thirty years ago.

Amongst more recent work in the Rhætic and Lias, I might mention papers by Mr. H. B. Woodward and Mr. Beeby Thompson, each in explanation of the arborescent figures in the Cotham Marble. The latter revives an old idea with modifications, and his theory certainly seems plausible. Mr. H. B. Woodward's Memoir of 1893 does full justice to the Lias of this district, and much original matter is introduced.

It is, however, in the Inferior Oolite that the most important interpretations have to be recorded since the days when Dr. Wright and Professor J. Buckman endeavoured to correlate the development of the series in the Cotteswolds with that in Dorset. To this subject I alluded at considerable length in my Address to the Geological Society in 1893, pointing out how much we owed in recent years to the late Mr. Witchell and to Mr. S. S. Buckman. In the following year appeared Mr. H. B. Woodward's Memoir on the Lower Oolitic Rocks of England ('Jurassic Rocks of Britain,' vol. iv.), wherein he did full justice to the work of previous observers. Meantime Mr. Buckman has not been idle, and his paper on the

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[1] *Quart. Journ. Geol. Soc.* vol. xlvii. (1891), p. 545.

[2] *Ann. Rep. Geol. Survey* for 1896, p. 67 (1897).

[3] *Quart. Journ. Geol. Soc.* vol. xxxvii. (1881), p. 67.

Bajocian of the Sherborne district[1] marks the commencement of a new era, where the importance of minute chronological subdivisions, based upon the prevailing ammonites, is insisted on with much emphasis. This system he considers to be almost as true for the Inferior Oolite as for the Lias.

There can be no doubt that its application has enabled Mr. Buckman to effect satisfactory correlations between the very different deposits of the Cotteswolds and those of Dorset and Somerset. In subsequent papers also he brings out an important physical feature—viz. the amount of contemporaneous denudation which has affected deposits of Inferior Oolite age in this country. This serves in part to explain the absence of well-known beds in certain areas. For instance, in the Cotteswolds contemporaneous erosion has, prior to the deposition of the Upper *Trigonia*-grit, cut right through the intervening beds, so as to produce in the neighbourhood of Birdlip a shelving trough 6 miles wide and about 30 feet deep. Thus the extensively recognised overlap of the *Parkinsoni*-zone is accentuated in many places.

We have a further instance of good work in the case of Dundry Hill. An inspection of the 1-inch Survey map would lead one to suppose that the Inferior Oolite there rests directly on the Lower Lias. Recently, owing to the investigations of Messrs. Buckman and Wilson,[2] this apparent anomaly has been removed, whilst beds of Middle and Upper Lias age, and even Midford Sands, have been recognised. In this way the authors claim to have reduced the thickness assigned to the Inferior Oolite on Dundry Hill by about 100 feet. In the paper above quoted the vicissitudes and faunal history of the Inferior Oolite from the *opalinus*-zone to the *Parkinsoni*-zone inclusive are shown with much detail; whilst the position of the chief fossil-bed in time and place has been well established. The general resemblance of the Dundry fossils to those of Oborne, which I could not fail to notice in working out the Gasteropoda of the Inferior Oolite, now admits of explanation. Although the quondam *Humphriesianus*-zone is richly represented, yet the particular *Humphriesianum*-hemera is held to be absent at Dundry. But if there is a *Sowerbyi*-bed anywhere it should serve to connect these two localities, where, according to Mr. Buckman's phraseology, the principal zoological phenomenon is the acme and paracme of Sonnininæ.

Mr. Buckman, as we have seen, is no longer satisfied with the old-fashioned threefold division of the Inferior Oolite, and his time-table includes at least a dozen hemeræ, with prospect of increase. Granting that it would have been difficult to solve the Dundry problem without a detailed knowledge of ammonite horizons, there arises the question as to the utility of such minute subdivisions for the purposes of general classification. Mr. Buckman has earned the right to put forwards, if he pleases, the several stratigraphical rearrangements in which from time to time he indulges. The Inferior Oolite has been his especial playground, and, as the kaleidoscope revolves, this formation is perpetually made to assume different proportions, even to the verge of extinction. But this practice is not without its disadvantages; whilst the invention of new names tends to clog the memory, and the novel use of old ones is apt to produce confusion.

We have not quite finished with Dundry yet, since that classic hill serves to illustrate in Mesozoic times a peculiarity of which I have already pointed out two notable instances in this district, where an abrupt and seemingly unaccountable difference is observed in beds which are approximately synchronous. The problem to be solved is this—why does the fossiliferous portion of the Inferior Oolite on Dundry Hill resemble that of the neighbourhood of Sherborne, both in lithology and fossils, rather than that of the Cotteswolds, only a few miles distant?

Nine years ago Mr. Buckman offered an ingenious solution of this difficulty;[3] though his recent investigations at Dundry, and especially his appreciation of the effects of contemporaneous erosion, may have caused him to alter his views. Like most people who wish to account for strong local differences, he placed a barrier of Palæozoic rocks between Dundry and the southern prolongation of the Cotteswold

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[1] *Quart. Journ. Geol. Soc.* vol. xlix. (1893), p. 479.

[2] *Quart. Journ. Geol. Soc.* vol. lii. (1897), p. 669. *Cf.* also *Proc. Brist. Nat. Soc.* vol. viii. (1897), pt. ii. p. 188.

[3] *Proc. Cottes. Club*, vol. ix. (1890), p. 374.

escarpment. At that time it was not fully realised that the Inferior Oolite in the Bath district is, for the most part, limited to the *Parkinsoni*-zone, so that the comparison was really being made between beds of different age as well as different physical conditions. The question resolves itself into one of local details, which are not suited for a general address. Still, I think it may be taken for granted that, notwithstanding the east-and-west barrier of the Mendip range, which acted effectually previously to the *Parkinsoni*-overlap, there was in some way a communication by sea between Dundry and Dorsetshire, more especially during the *Sowerbyi*-stage, and this most probably was effected round the western flank of the Mendips. Thus, without acceding to the necessity for a barrier facing the Southern Cotteswolds, we may readily believe that much of the Inferior Oolite of Dundry Hill is to be regarded as an outlying deposit of the Anglo-Norman basin. If this be so, it is difficult to avoid the conclusion that the low-lying area of the Bridgewater flats was, during part of the Inferior Oolite period, occupied by a sea which was continuous from Sherborne to Dundry, and that, although the barrier of the Mendips was interposed, communication was effected round the west flank of that chain. This would make a portion of the Bristol Channel a very ancient feature.

We must now take a wide leap in time, passing over all the rest of the Jurassics, and just glancing at the Upper Cretaceous system, which reposes on the planed-down surface of the older Secondary rocks. The remarkable double unconformity is nowhere better shown than in the South-west of England. Some of the movements of the older Secondary rocks, prior to the great revolution which brought the waters of the Cretaceous sea over this region, have been successfully localised by Mr. Strahan, more especially in the south of Dorset.

Owing to Tertiary denudation the Chalk in this immediate district has been removed, and we have no means of judging the relations of the Cretaceous deposits to the Palæozoic rocks of Wales. If we may judge by results recently recorded from Devonshire,[1] the Lower Chalk especially undergoes important changes as it is traced westwards, and generally speaking terrigenous deposits seem more abundant in this direction. At the same time the more truly oceanic deposits, such as the Upper Chalk, appear to be thinning. As regards the possible depths of the Cretaceous sea at certain periods, we are supplied with some interesting material in Mr. Wood's two papers on the Chalk Rock,[2] which has been found especially rich in Gasteropoda at Cuckhamsley, near Wantage.

Tertiary, Pleistocene, and Recent.—Although the Tertiaries of the Hampshire basins are within the 'Index-map' which we have been considering, they may be regarded as beyond our sphere. Some of the gravels of Dorsetshire, which have gone under the name of plateau gravels, are held by Mr. Clement Reid to be of Bagshot age. Many of the higher hill gravels most likely date back to the Pliocene, and even further, and represent a curious succession of changes, brought about by meteoric agencies, where the valley-flat of one period, with its accumulated shingle, becomes the plateau of another period—an endless succession of revolutions further complicated by the Pleistocene Cold Period, which corresponds to the great Ice Age of the North.

In the more immediate neighbourhood of Bristol, since some date in Middle Tertiary time, the process of earth-sculpture, besides laying bare a considerable amount of Palæozoic rock, has produced both the Jurassic and Cretaceous escarpments as well as the numerous gorges which add so much to the interest of the scenery. These phenomena have been well described by Professor Sollas,[3] when he directed an excursion of the Geologists' Association in 1880. Should any student wish to know the origin of the gorge of the Avon at Clifton, for instance, he will find in the Report an excellent explanation of the apparent anomaly of a river which has been at the trouble of sawing a passage through the hard limestone, when it might have taken what now seems a much easier route to the sea by way of Nailsea.

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[1] *Cf.* Jukes-Browne and Hill, *Quart. Journ. Geol. Soc.* vol. lii. (1897), p. 99.

[2] *Quart. Journ. Geol. Soc.* vol. lii. (1897), p. 68, and vol. liii. (1898), p. 377.

[3] *Proc. Geol. Assoc.* vol. vi. (1881), p. 375.

The origin and date of the Severn Valley is a still bigger question, and this was broached by Ramsay, some five-and-twenty years ago, in a suggestive paper on the River Courses of England and Wales.[1] He there postulates a westerly dip of the chalk surface, which determined the flow of the streams in a westerly direction towards the long gap which was being formed in Miocene times, near the junction of the Mesozoic with the Palæozoic rocks. The still more important streams from the Welsh highlands had no doubt done much towards initiating that gap; and by the end of the Miocene period, if one may venture to assign a date, the valley of the Severn, which is one of the oldest in England, had already begun to take form, though many of the valleys of Wales are probably much older.

We may now be supposed to have arrived at a period when the physical features of this immediate district did not differ very materially from what they are at present. The great Ice Age was in full force throughout Northern Europe, and, according to views which meet with increasing favour, the German Ocean and the Irish Sea were filled with immense glaciers. What was taking place at that time in the estuary of the Severn?

This is a case which requires the exercise of the scientific imagination, of course under due control. There is probably nothing more extraordinary in the history of modern investigation than the extent to which geologists of an earlier date permitted themselves to be led away by the fascinating theories of Croll. The astronomical explanation of that 'will o' the wisp,' the cause of the great Ice Age, is at present greatly discredited, and we begin to estimate at their true value those elaborate calculations which were made to account for events which in all probability never occurred. Extravagance begets extravagance, and the unreasonable speculations of men like Belt and Croll have caused some of our more recent students to suffer from 'the nightmare.'

Nevertheless Croll, when he confined his views to the action of ice, showed himself a master of the subject, and his suggestions are often worthy of attention, even when we are not convinced. Writing in the 'Geological Magazine' in 1871, he points out that the ice always seeks the path of least resistance; and he refers to the probability that an outlet to the ice of the North Sea would be found along the natural hollow formed by the valleys of the Trent, the Warwickshire Avon, and the Severn. Ice moving in this direction, he says, would no doubt pass down into the Bristol Channel and thence into the Atlantic. Again,[2] referring to the great Scandinavian glacier, he says, 'it is hardly possible to escape the conclusion that a portion of it at least passed across the South of England, entering the Atlantic in the direction of the Bristol Channel.' These views were not based on any local knowledge, but merely on general considerations. The problem as to whether there are any traces of the passage of such a body of ice in the basin of the Lower Severn must be worked out by local investigators. Irrespective, too, of the hypothetical passage of a lobe of the North Sea glacier, we are confronted by a much more genuine question, namely, what was the possible termination towards the south of the great body of ice with which our more advanced glacialists have filled the Cheshire plain.

A recent President of the Cotteswold Field Club, of whom unfortunately we must now speak as the late Mr. Lucy, took a lively interest in the Pleistocene geology of the district, and his papers in the 'Proceedings' of the Cotteswold Field Club have always attracted attention. His map of the distribution of the gravels of the Severn, Avon, and Evenlode, and their extension over the Cotteswold Hills, prepared in conjunction with Mr. Etheridge, is a valuable contribution to the history of the subject.[3] Again he wrote on the extension of the Northern Drift and Boulder-clay over the Cotteswold Range,[4] and on this occasion described the interesting section in the drifts presented by the Mickleton Tunnel. In his previous paper, Mr. Lucy had carried the drifts with northern erratics to a height of 750 feet,

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[1] *Quart. Jour. Geol. Soc.* vol. xxviii. (1872), p. 148.

[2] *Op. cit.* Dec. 2, vol. i. (1874), p. 257.

[3] *Proc. Cottes. Nat. Club*, vol. v. pt. ii. (1869) p. 71.

[4] *Op. cit.* vol. vii. pt. i. (1878), p. 50.

but he now claimed that 'the *whole* Cotteswold Range had ceased to be dry land at the time the Clays and Northern Drifts passed over it.' We perceive from this passage that Mr. Lucy was a 'submerger,' and in this respect differed from Croll, who most probably would have attributed the phenomena to the action of his great ice-lobe traversing the South of England.

The question which more immediately concerns us relates to the value of the evidence which would require either a glacier or a 'great submergence' to account for these things. The alleged phenomena are in many cases capable of other interpretations. We have the authority of Mr. Etheridge that little or no true Boulder-clay occurs in the Cotteswold area.[1] On the other hand, the distribution of much of the erratic gravel is probably due to agencies of earth-sculpture long anterior to the great Ice Age. There remains one special piece of evidence adduced by Mr. Lucy in favour of his contention, and this he considered of so much importance that it formed the principal part of the subject of his annual address to the Field Club on quitting the chair in 1893.[2]

He there referred more especially to the discovery *in* the Inferior Oolite, on Cleeve Cloud, of quartzose sand and of a boulder of a similar character to some described in his previous papers. The sand and the boulder, he says, belong to the period of the great submergence. Similar sand also appears in several places on the hillside. He had previously recorded boulders of Carboniferous Limestone, Millstone Grit, &c., in the Northern Cotteswolds, but not at so great an elevation. He further proceeds to account for the absence of striæ, and of the fact that the Cotteswold rocks are not *moutonnée*, on the supposition that the soft oolites would not retain striation, but would be crushed by pressure. Consequently, he claims the top of Cleeve Cloud as a fine example of 'glacial denudation,' whatever that may mean. The boulder from Cleeve Cloud is now in the Gloucester Museum, and might well become a bone of contention between the submerger and the glacialist as to how it got into its elevated position of over 1,000 feet. Fortunately there is a third explanation, which, if it be correct, shows how dangerous it is to build theories, as well as houses, upon sand. Other distinguished members of the Cotteswold Club are of opinion that the whitish sands on Cleeve Common belong to the 'Harford Sands,' which constitute an integral part of the Inferior Oolite itself. There may be some difference of opinion as to the concretionary nature of the boulders, though these may well be nothing more than the 'doggers,' or 'potlids,' so characteristic of calcareous sandstones. Mr. Winwood believes that 'the so-called foreign boulder' in the Gloucester Museum evidently came from the 'Harford Sands.'

So far, therefore, the evidences of glacial action in the Cotteswolds do not rest on a very sure foundation. Yet the Severn Valley separates that range from an area on the west, where there are clear evidences of local glaciation, as described in the 'Annual Report of the Geological Survey for 1896.' Portions of this material find their way into the river bed and elsewhere as Drift which has most probably been rearranged—hence the so-called Boulder-clay and Drift in the bed of the Severn. Once more, then, in the cycle of geological time we perceive that our district lies on the confines of two distinct sets of phenomena. West of the Severn and north of the Bristol Channel the evidences of considerable local glaciation are obvious, whilst this can hardly be said of the Cotteswolds, the Mendips, or the Quantocks.

To the more recent geological history of our district it will be sufficient to allude in the briefest terms, when I remind you of the paper by Mr. Strahan on the deposits at Barry Dock, and the still later one by Mr. Codrington on the submerged rock valleys in South Wales, Devon, and Cornwall. Here we have important testimony to certain moderate changes of level which have taken place, and a picture is presented to us of the Bristol Channel as a low-lying land surface, with streams meandering through it. Thus a depression of something like 60 feet appears to be the most recent change which the geologist has to record in the estuary of the Severn.

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[1] *Proc. Cottes. Nat. Club*, vol. xi. (1893), p. 83.

[2] Vol. cit. p. 1.

The following Papers and Reports were read:—

1. *Notes on the Geology of the Bristol District.* *By* Professor C. LLOYD MORGAN, *F.G.S.*

(*a*) The chief features of the Silurian district of Tortworth were briefly described. Attention was drawn to the probably contemporaneous Upper Llandovery volcanic action. One or two new facts, as given in the 'Guide' to the excursion to this locality, were alluded to. (*b*) The division of the Carboniferous Limestone (between the Upper and Lower Limestone Shales) into an Upper and Lower Series with a band of Oolite, the Gully Oolite, between them, was illustrated by typical sections in the Bristol district. (*c*) An interbedded volcanic series near the top of the Lower Limestone at Woodspring, near Weston, was illustrated by a map and photographs from microscopic sections. (*d*) Slides were shown illustrating the unconformabilities of the district, and a sketch map of the islands in late Triassic times was briefly described. (*e*) An attempt was made to illustrate, by means of a diagram based on careful observations, the amount of superficial contraction due to post-Carboniferous lateral pressure.

2. *The Building of Clifton Rocks.* *By* E. B. WETHERED, *F.G.S.*

In this paper the author confines his remarks chiefly to the microscopic life which he has discovered in the Carboniferous Limestone rocks at Clifton. He contends that microscopic calcareous organisms have been the chief contributors to the vast deposits in the Carboniferous sea, now represented by the cliffs on either side of the gorge of the Avon at Clifton.

Broadly speaking, there were three stages in the formation of this limestone. These were regulated by physical conditions, and favoured the existence of certain forms of life. The fossil remains now denote the stages. They are as follows:—

	Approximate Thickness
Stage 1. Lower Limestones (including the Lower Limestone shales 500 feet, and Black Rock series 470 feet	990 feet
Stage 2. Middle Limestone	1,620 „
Stage 3. Upper Limestone	100 „

The close of the Old Red Sandstone Period is marked by variegated sandstones and shales. These beds pass into limestones and shales, and these again are followed by massive limestones locally known as the Black Rock; the whole representing the Lower Limestones, or Stage 1.

During this stage encrinites were so numerous in the waters that the ossicles of these creatures are a distinguishing feature of the limestones. Vast numbers of ostracoda at times lived, and some beds of the limestone are chiefly accumulations of the remains of these small crustaceans. Monticulipora corals and polyzoa were numerous in the waters, and also mollusca.

Another interesting feature, not before noticed in the Lower Limestones, is the mass of incrusting organisms. These organisms formed a crust around the fragmental remains of other organisms which collected on the sea floor, and to such an extent did this process go on that the incrusting organisms contribute considerably to the building up of some beds of limestone. Whether these crusts are to be attributed to animal or vegetable growth is a matter of doubt.

The crinoidal life reached a climax during the time that the Black Rock Limestone was in process of formation. Indeed, this rock is, in the main, a vast accumulation of the ossicles of these creatures, associated with shells of mollusca, fish remains, &c.

The Black Rock series terminate in dolomitised limestone, and on this rest the 'Gully Oolites.'

The Lower Limestones terminate at these oolites, in which occur, though sparingly, foraminifera and the minute spherical object calcisphæra. This latter body averages about ·012 of an inch in diameter, but, small as it is, the calcareous sphere has been an important contributor to the building of the rocks.

As calcisphæra is confined to the Carboniferous Limestone, and is so numerous that it is seldom a thin section of the rock is obtained without finding it, the organism is useful in determining the strata when doubtful. So far, the author has not found calcisphæra in the Lower Limestones, and the same remark applies to foraminifera.

Above the horizon of the Gully Oolite the lower beds of the Middle Limestone are characterised by the occurrence of the curious organism *Mitcheldeania*, but it is not confined to this horizon.

Next follow limestones and calcareous shales full of the remains of little-understood forms of microscopic life, which must have existed in great profusion.

As before remarked, the Middle Limestones are characterised by foraminifera and calcisphæra. At first these occur sparingly, but, later on, the rock is little more than a Carboniferous foraminiferous ooze. Remains of corals occur and other well-known fossils, but the bulk of the 1,600 feet of limestone included in the Middle Series is in the main a vast calcareous deposit of the remains of microscopic life which lived in the Carboniferous waters.

Owing to the Upper Limestones being so built over, the author is at present not in a position to describe the microscopic life which the strata probably contain associated with large organisms.

3. *On the Revision of South Wales and Monmouthshire by the Geological Survey. By* A. STRAHAN.

[Communicated by permission of the Director-General.]

The original geological survey of South Wales was made under the direction of Sir Henry De la Beche. The exact date of its commencement is uncertain, but I am informed by Mr. Aveline that in 1840, when he joined, the staff was engaged in the neighbourhood of Cardiff, and in 1841 Ramsay on his appointment found that the survey had progressed westwards into Pembrokeshire and was at work at Tenby and St. David's.[1] By the end of 1845 the maps had all been published. A complete list of the names which appear on them consists of H. T. De la Beche, J. Phillips, D. H. Williams, A. C. Ramsay, W. T. Aveline, J. Rees, T. E. James, W. E. Logan, H. W. Bristow,[2] and H. B. Woodward.[2]

Previously, however, to the entry of the Survey into South Wales a considerable tract had been mapped by Sir W. E. Logan. 'Unaided he commenced, in 1831, a geological survey of part of the great South Welsh Coal-field, extending from Crown (Cwm) Avon to Carmarthen Bay, and completed it in seven years, at no small pecuniary sacrifice. Such was the estimate of the accuracy and value of this survey by the late Director of the Geological Survey of Great Britain, Sir Henry De la Beche, that with Sir William's consent it was adopted as part of the national work.'[3] At the meeting of the British Association in Liverpool in 1837 Logan exhibited his work, and in 1842 it was referred to by De la Beche as a beautifully executed map.[4] After the lapse of nearly fifty years these maps, admirable though they were, considering their date and the circumstances under which they were made, had become obsolete. Not only was the topography scarcely recognisable, but the development of the steam-coal trade had led to the opening out of many of the Monmouthshire and Glamorganshire valleys and the working of what was practically a virgin coal-field. On June 8, 1891, in the House of Commons, Lord Swansea (then Sir Hussey Vivian) asked the Vice-President of the Council whether, in view of the great importance of the South Wales and Monmouthshire Coal-field

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[1] *Memoir of Sir Andrew Crombie Ramsay*, by Sir Archibald Geikie, 1895, p. 42. London, 8vo.

[2] Revisions chiefly of the Secondary Rocks in 1864, 1871, and 1872.

[3] An article in the *Times* of July 24, 1862, by Dr. Percy, quoted in *Life of Sir William E. Logan, Kt., LL.D., F.R.S., F.G.S.*, by B. J. Harrington, 1883, p. 349. London, 8vo.

[4] *Ibid.*, p. 127.

and the fact that the coalfields of Durham, Northumberland, Yorkshire, and Lancashire had been for the most part geologically surveyed on the 6-inch scale, he would give directions that the geological survey of the mineral districts of South Wales and Monmouthshire should be immediately taken in hand and vigorously prosecuted on that scale. Answer was made that it would be arranged with the Director-General that the survey should be commenced as soon as possible and prosecuted as vigorously as the size of the disposable staff of the surveyors and the exigencies of the other branches of the work would allow. The revision was commenced five weeks later, and its progress up to date forms the subject of the following note.

Until the year 1893 I was engaged alone upon the revision, but in that year I was joined by Mr. W. Gibson, in 1894 by Mr. J. R. Dakyns, and in 1895 by Mr. R. H. Tiddeman. In 1896 Mr. Dakyns retired, and his place was taken by Mr. T. C. Cantrill.

The area over which the revision will extend is embraced in the New Series 1-inch Ordnance Maps, 226-232, 244-249, 261-263, sixteen sheets altogether, and amounts to a little over 2,000 square miles. Of these, three sheets (249, 232, 263) have been published, one (248) is being engraved, while the surveying of two more (231, 262) is nearly complete. The total area surveyed by the end of 1897 amounted to 1,006 square miles, in which 5,011 miles of geological lines had been traced upon the maps.

The work is engraved on the 1-inch New Series Ordnance Maps only, but the lines are all traced in the field on the 6-inch maps. Clean copies of these working maps are deposited in the Office, and can be consulted or copied as soon as the corresponding 1-inch sheet is published. At the same time sheets of vertical sections illustrating the Coal Measures are prepared: two of these, giving series of shaft-sections in Monmouthshire and Eastern Glamorganshire, have been published, and others are in preparation. Explanations to accompany each sheet of the map are also being written: in these the local geology will be briefly explained; but it is proposed to describe the Coal-field as a whole in a separate volume when the revision is complete.

I take this opportunity of acknowledging, on behalf of my colleagues and myself, the invaluable assistance which we have received from the managers, engineers, and surveyors in our work in the Coal-field. Without such aid the mapping would have been impossible, and the unvarying courtesy with which it was rendered has greatly facilitated a task that was far from easy. Of the important information recorded in the 'Proceedings' of the South Wales Institute of Engineers, and the Cardiff Natural History Society also, we have freely availed ourselves, acknowledgment of all of which will be made in due course.

In order that the map of the Coal-field should present the structure as conspicuously as possible, it was necessary to subdivide the great mass of Coal Measures which had been represented by one tint only on the old map. At the eastern end of the field it was apparent that a suitable threefold division of the strata held good, the three divisions not only differing in their mineral contents, but presenting such physical features as lent themselves to the purposes of the geological surveyor. I wish, however, to point out that no correlation is intended with the Upper, Middle, and Lower Coal Measures of other fields. Not only is it extremely improbable that any representatives of the Upper Coal Measures exist, but it is an open question how much of the Middle Coal Measures are present in South Wales. The subdivisions referred to consist of—

1. An upper series of shales and felspathic sandstones with a few thin seams of coal and ironstone. The sandstones are often indistinguishable from Pennant, but the series is softer on the whole and forms cultivated land of flowing contour. For its base the Mynyddislwyn Vein, a valuable and constant house-coal, served conveniently.

2. The Pennant Series, which in Monmouthshire is made up almost wholly of hard current-bedded highly felspathic grit with a few thin and impersistent coal seams. This series forms uncultivated moorlands, intersected by deep valleys

with rugged sides. At its base occurs the seam variously known as the Red Ash, Tillery, Brithdir, or No. 2 Rhondda.

3. The Lower Coal Series (Steam Coal Series of Glamorganshire), which consists principally of shales and thin beds of quartz-grit. This series contains the thickest seams of coal and the bands or nodules of clay-ironstone which were formerly worked in South Wales. It crops out all along the margin of the Coal-field, but is exposed only in the deepest valleys or along the crests of the anticlines in the more central parts.

Through the eastern end of the field these three subdivisions are readily distinguished, but they expand rapidly westwards, and at the same time sandstones not to be distinguished from Pennant appear in the upper part of the lower series, while measures of the supra-Pennant type replace the upper grits of the Pennant group. They continue, however, to form the most suitable broad divisions that could have been selected, though a further subdivision may become necessary in view of their increasing thickness.

The other rock-groups have been treated on similar principles. The Old Red Sandstone of Monmouthshire at once lends itself to division into an upper series of grits and quartz-conglomerates, a thick mass of red sandstones, and a great underlying deposit of red marls with thin limestones. Special attention has been paid to the relations of these subdivisions to one another in view of the possibility of an unconformity having remained undetected in the middle of the red strata; but though the grits and quartz-conglomerates disappear in Brecknock, no break of any significance in the sequence has yet been discovered. The conformity of the Old Red Sandstone to the Upper Silurian rocks of Usk, however, may prove to be more apparent than real, and must remain an open question for the present.

The Carboniferous Limestone also expands westwards and southwards, for, while only 100 feet thick at Abergavenny, it is 500 to 700 feet in northern Glamorganshire, and attains still greater dimensions in the southern part of that county. The lower portion consists of shales with a more or less persistent limestone below, which constitute the Lower Limestone Shales. In the main mass no subdivision has been made, except that certain light-coloured oolitic bands have been picked out.

The mapping of the Millstone Grit is founded on purely lithological distinctions. Over a large part of the north-eastern crop it consists of a grit (the Farewell Rock of old miners) in the upper part; shales, and sandstones, occasionally with some coal and ironstone, in the middle; and a massive grit, usually crammed with quartz-pebbles, in the lower part. This order, however, does not hold good everywhere, and shales and sandstones are traced as far as practicable, and merely coloured on the map as such. Though perfectly conformable to the limestone, the oncoming of the quartz-conglomerates seems to have been accompanied by some erosion, for they fill small hollows in the topmost limestone, and are even suspected of cutting across some of the beds, so as to simulate an unconformity. Matters are further complicated by the fact that the upper surface of the limestone has undergone extensive dissolution during later ages.

Some fossils which occur in calcareous shales and thin impure limestones in the lower and middle parts of the Millstone Grit are all marine, but in the upper part *Anthracomya* becomes the abundant shell, and indicates an approach to Coal Measure conditions. Marine forms, however, recur at intervals high up in the Lower Coal Series. It will be noticed that there is nothing corresponding to the 'Yoredale Rocks,' or upper part of the Carboniferous Limestone Series of the North of England, nor to the alternating series of sandstones and limestones which border the Flint and Denbigh Coal-fields.

The Secondary Rocks which fall within the revised area include Trias (Keuper or New Red Marl), Rhætic and Lower Lias. These strata were deposited along a land which was undergoing gradual submergence after prolonged exposure to subaërial denudation. The New Red Marl, consequently, was irregularly distributed in what must have been bays diversified by numberless islands, and the old shore-lines, though subsequently buried, have been revealed by denudation, so that it is often possible to examine the cliffs against which the Triassic waves beat and the talus, more or less water-worn, which fell from them. The continued sinking of the land led not only to the Rhætic overspreading the Trias, and extending beyond it, but to the Lias eventually overlapping all earlier deposits. Each formation, as it overlaps its predecessor and comes into contact with the Palæozoic rocks, becomes conglomeratic, and it thus happens that a conglomeratic subdivision though actually continuous is of Triassic, Rhætic, and Liassic age in different parts of its outcrop; a state of affairs which is not easily represented by the usual methods of colouring a geological map.

The boundary between the New Red Marl and the Rhætic has hitherto been taken at the base of some green marls which graduate downwards into the Red Marls, but during the revision it became evident that the only satisfactory base to the Rhætic occurred above the Green Marls and at the base of the black shales of the *Avicula contorta* zone. At this horizon there is generally a grit or small quartz-conglomerate which taken with the incoming of the Rhætic fauna indicates a somewhat sudden change of physical conditions. It marks, in fact, the first complete invasion of this area by the sea.

One of the most important parts of the revision has consisted in the tracing of the various folds and faults through the Coal-field. The main anticlinal and synclinal axes are of course brought into prominence on the map by the subdivision of the measures before referred to. Thus the difference of tint shows the positions of the two deep synclines which introduce the Upper Coal Series at Caerphilly and Llantwit on the south side, and at Blackwood and Gelligaer on the north side of the main anticline; while the anticlinal axis is itself brought into prominence by the fact that it brings the Lower Coal Series up to the surface at intervals along its course. Especially, also, attention may be directed to the contrast presented by the long dip-slopes of the north crop of the Coal-field to the straight and narrow strips along the highly inclined south crop. Of the numerous flexures which have been traced in the Palæozoic rocks outside the Coal-field it is sufficient to state that they run in about the same direction as those mentioned above, and that they do not affect the Secondary Rocks, which in fact pass horizontally across them. These east and west flexures are consequently assumed to be pre-Triassic.

To this series also we believe the great Vale of Neath disturbance and some other kindred folds to belong. This great faulted fold seems to have attracted but little notice hitherto, though it displays many remarkable features, among others a thrust by which Carboniferous Limestone has been pushed over a large thickness of Millstone Grit. It will be remembered that the Carboniferous Rocks of Somerset were still more intensely plicated and overthrust in pre-Triassic times, and that there also the disturbances run in a general east and west direction.

The set of faults which run about north-north-west with such remarkable persistency is a well-known feature of the Coal-field. Some of them can be traced out into the Secondary area, and are there found to dislocate the Secondary Rocks equally with the Carboniferous. While, therefore, they are obviously post-Liassic, they may be of very much later date.

The exact representation of the faults, of whatever age, upon the map is of the greatest importance in the Coal-field, and is managed as follows:—The surface-position of the fault is indicated by a white line, or by a broken white line where the exact position is uncertain. If the fault has been proved in the workings of the Mynyddislwyn Vein, its underground position in that vein is shown by a red line, if in the Tillery Vein by a yellow line, and if in the Lower Coals by a blue line. Thus a normal fault completely proved would be represented by four lines, the order in which the lines occur indicating the direction, and their distance apart the angle of the hade. A further difficulty remains, however; for the plan-position of a fault encountered in any vein in working up to it from the east would not be the same as the plan-position of the same fault in the same vein if worked up to from the west, owing to the hade. In a fault of 100 yards the discrepancy would amount to 35 or 40 yards, and it becomes necessary to record also from which side the fault was proved, which is not always easily ascertained in old workings. The coloured lines referred to are used on the 6-inch maps only; on the 1-inch maps the underground faults are all shown by yellow lines to avoid undue complication.

The glacial deposits are mapped simultaneously with the solid geology, and are shown on the edition of the map for superficial geology. With the exception of the admirable work of Prof. Edgworth David, and sundry observations by the Rev. W. S. Symonds, they have not attracted so much attention as they deserve, for South Wales formed a small independent centre of glaciation and exhibits phenomena of great interest. The greater water-partings of the present day formed the ice-partings of the Glacial Period, and the principal valleys gave the route to the ice-flow. Thus a great mass of drift was transported from Brecknock round the north-east corner of the Coal-field down the Usk Valley as far as the depression occupied by the Usk Branch Railway. Another part was pushed over a minor water-parting into the Rhymney Valley, but principally escaped along the Taff Valley, traversing the entire Coal-field and emerging by the ravine at Walnut Tree; while a third portion flowed south-westwards along the Neath and other valleys towards Swansea Bay. The drift consists in part of coarse gravels or fine gravel and sand, and forms characteristic mounds or ridges between which are inclosed innumerable water-logged hollows, or meres. Nearer to its source, however, it becomes an extremely tough boulder clay packed with glaciated boulders. The composition of the deposit, the direction of the longer axes of the mounds, and, lastly, a large number of striations on rock-in-place combine in determining the directions assigned to the ice-flow. The southern limit to which the ice reached is no less clearly marked than its birthplace, for the gravels get finer and thinner, and eventually die away, sometimes before reaching the shores of the Bristol Channel.

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4. *On the Exploration of two Caves at Uphill, Weston-super-Mare, containing remains of Pleistocene Mammalia. By the late* EDWARD WILSON, *F.G.S.*

[Communicated by HERBERT BOLTON, F.R.S.E.]

Quarrying operations now proceeding in the Carboniferous Limestone near the old parish church of Uphill have led to the discovery of two caves.

The caves are about half way up the face of the quarry, which is 100 feet in height. The floor of each cave is covered with a deposit which varies from 1 to 2 feet in thickness.

A typical section of the upper cave deposits is as follows:—

	Ft.	In.
1. Deep purplish-red, soft, sandy Marl, containing blocks of Limestone	4	0
2. Greenish-yellow, soft, sandy Marl	1	2
3. Greenish-drab argillaceous Sandstone	5	6
4. Limestone floor.		

The Green Marl for a varying thickness in different parts of the cave becomes brecciated and occasionally tufaceous.

The animal remains are contained in this bed, and consist chiefly of the teeth and jaws of hyæna, with gnawed and ungnawed bones of horse, mammoth, cave-bear, fox, &c.

The lowest of the two caves is partly filled with a deposit of coarse rubble, and has yielded remains of hyæna, rhinoceros, and the teeth and jaws of small carnivora and rodents, together with worked flints, and a number of rounded stones supposed to have been used as pot-boilers. The rubble deposit has evidently undergone a certain amount of displacement, so that it is by no means certain that the remains contained in it are contemporaneous.

5. *The Comparative Actions of Subaërial and Submarine Agents in Rock Decomposition.* *By* THOMAS H. HOLLAND, *A.R.C.S., F.G.S., Geological Survey of India.*

In Europe, nearly all crystalline and igneous rocks of any considerable age show signs of hydrous decomposition, which by the microscope can generally be traced far beyond the limits of the very evident superficial crust of weathered products: in some cases, like the peridotites, the changes due to hydration, even in rocks of Tertiary age, have resulted in a practically complete alteration of the original constituents. In working over various parts of Peninsular India, the writer has been struck by an almost constant absence of any but the most superficial traces of hydration, even in minerals like olivine and nepheline, which are so noticeably susceptible to the action of water. As in all tropical and moist climates, however, a complete and rapid superficial decomposition is shown by most of the rocks, and in some areas they are found to be changed into a ferruginous clay, which, though forty or fifty feet thick, is found to retain the characteristic macroscopic structures of the original rocks. In some districts, where the atmosphere is always warm, and during the monsoon season highly charged with moisture without great precipitation of rain, the rocks are similarly decomposed at the surface, but, on account of the limited amount of running water, the lime is retained in the decomposition products, and forms a concretionary 'kankar.'

In all these cases, however, although the action of the atmosphere is so striking, the results are purely superficial, and a specimen of rock taken from within a few inches of the clay products seldom shows a trace of hydrous decomposition, even in thin sections under the microscope. This is just as true for such delicate minerals as olivine and nepheline as for the commoner silicates. In many of the basic dykes, certainly pre-Cretaceous and probably Lower Palæozoic in age, the absence of serpentine is so complete that unusual precautions are often necessary for the determination of the olivine, whilst in the numerous occurrences of dunite throughout the Madras Presidency serpentine is extremely scarce. In a nepheline syenite recently discovered in the Coimbatore district, and at least of Cuddapah age, the nepheline on microscopic examination shows mere traces of alteration along the fracture cracks.

In the light of European experience, where most of our petrographical data have been established, the peculiarities of the Madras rocks call for some special consideration, and the object of this paper is to suggest that the probable explanation of the peculiarities now referred to arises from a contrast of the geological histories of the two areas. In Europe all, or nearly all, the rocks have been submerged below the sea during the later geological periods; in South India there is no evidence beyond the immediate precincts of the coast-line of any depression below sea-level since Cuddapah (probably lower Palæozoic) times. In Europe, therefore, the features generally attributed to weathering are the compound effect of submarine and subaërial action; in South India the former class of agencies have not affected the rocks now exposed, and the remarkable freedom from hydration which they show suggests that the action of the atmospheric agencies is purely superficial.

Taking into consideration the presence of lime carbonate and other salts, with a larger proportion of carbonic acid and the great pressure under which sea-water attacks a submerged rock mass, it is theoretically to be expected that submarine agencies are more potent means of decomposition than those of the atmosphere; but these South Indian observations tend to show that serpentine and other forms of hydrated products within rock-masses are due only to a very limited degree to true weathering.

The products of atmospheric action are removed from the rock surface as fast as they are formed, and deeper portions are *pari passu* brought to the surface. It is not improbable that it is on account of this denudation, which has proceeded without known interruption for so many geological ages, that relatively deep-seated portions of the Earth's crust have been brought to the surface in Madras, and that the crystalline rocks there met with at times present peculiarities for which European experience hardly prepares us.

6. *On Arborescent Carboniferous Limestone from near Bristol.*

By Horace B. Woodward, *F.R.S.*

A specimen of Carboniferous Limestone, showing arborescent markings, was obtained by Mr. Spencer G. Perceval from Brentry Hill, near Henbury, Bristol, and was presented by him in 1897 to the Museum of Practical Geology. The rock is about 6 inches thick, and the lower half is a current-bedded oolitic limestone. The upper half comprises banded calcareous mud with a few layers of oolitic grains, and the material in this portion of the rock has been disturbed, the layers having been bent; while the hollows between the curves are partially eroded and filled with irregular detrital material containing oolitic grains.

The surface of the block presents an irregular concretionary structure, resembling that seen on many varieties of Cotham Marble; but it is not so pronounced as in some of the mammillated surfaces seen in that rock.

The appearances are probably due to mechanical disarrangement of the upper layers produced prior to and during the consolidation of the rock, and they suggest a pause in the deposition of sediment.

It is noteworthy that the darker bands which produce the arborescent markings stand out slightly in relief on the weathered face of the block of Carboniferous Limestone. This is also the case with an example of Cotham Marble which I lately obtained on the South Wales Direct Railway at Stoke Gifford.

A small specimen of Carboniferous Limestone from Backwell, near Nailsea, given to me by Mr. W. H. Wickes, shows indications of arborescent markings. [Further references to the subject are given in the 'Geol. Mag.,' Dec. 3, vol. ix., 1892, p. 110; see also B. Thompson, 'Quart. Journ. Geol. Soc.,' vol. l., 1894, p. 393.]

7. *Report on Photographs of Geological Interest in Britain.*

See Reports, p. 530.

8. *Report on Photographs of Geological Interest in Canada.*

See Reports, p. 546.

FRIDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *The Comparative Value of Different Kinds of Fossils in Determining Geological Age.*

By Professor O. C. Marsh.

More than twenty years ago my attention was called to the subject of the difference between the value of fossil Plants, Invertebrates, and Vertebrates, as evidence of the geological age of the strata in which they were preserved. On the comparative value of these different groups of fossils then depended the solution of some grave problems in the geology of the Rocky Mountains. I therefore began a systematic investigation of this subject, and gave the results in an address before the American Association for the Advancement of Science in 1877.[1] I stated the case as follows:—

'The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is

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[1] *American Journal of Science*, vol. xiv. pp. 338–378, November, 1877.

uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favour of the former view.

'This brings up an important point in palæontology, one to which my attention was drawn several years since—namely, the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organisation or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves.'

In the statement I have quoted, I had no intention of reflecting in the slightest degree on the work of the conscientious palæobotanists who had endeavoured to solve the problem with the best means at their command. I merely meant to suggest that the means then at their command were not adequate to the solution.

It so happened that one of the most renowned of European botanists, Sir Joseph Hooker, was then in America, and to him I personally submitted the question as to the value of fossil plants as witnesses in determining the geological age of formations. The answer he made fully confirmed the conclusions I had stated in my address. Quoting from that, in his next annual address as President of the Royal Society, he added his own views on the same question.[1] His words of caution should be borne in mind by all who use fossil plants in determining questions of geological age.

The scientific investigation of fossil plants is an important branch of botany, however fragmentary the specimens may be. To attempt to make out the age of formations by the use of such material alone is too often labour lost, and must necessarily be so. As a faithful pupil of Goeppert, one of the fathers of fossil botany, I may perhaps be allowed to say this, especially as it was from his instruction that I first learned to doubt the value of fossil plants as indices of the past history of the world. Such specimens may indeed aid in marking the continuity of a particular stratum or horizon, but without the reinforcement of higher forms of life can do little to determine the age.

The evidence of detached fossil leaves and other fragments of foliage that may have been carried hundreds of miles by wind or stream, or swept down to the sea-level from the lofty mountains where they grew, should have but little weight in determining the age of the special strata in which they are imbedded, and failure to recognise this fact has led to many erroneous opinions in regard to geological time. There are, however, fossil plants that are more reliable witnesses as to the period in which they lived. Those found on the spot where they grew, with their most characteristic parts preserved, may furnish important evidence as to their own nature and geological age. Characteristic examples are found among the plants of the Coal Measures, in the Cycads of Mesozoic strata, and in the fossil forests of Tertiary and more recent deposits.

The value of all fossils as evidence of geological age depends mainly upon their degree of *specialisation*. In the invertebrates, for example, a Linguloid shell from the Cambrian has reached a definite point of development from some earlier ancestor. One from the Silurian or the Devonian, or even later formations, however, shows little advance. Even the recent forms of the same group have no distinctive characters sufficiently important to mark geological horizons.

If we take the Ammonites as another example from the Mollusca the case is totally different. From the earliest appearance of this family the members have been constantly changing, developing new genera and species, each admirably adapted to mark definite zones or horizons, and already used extensively for that purpose.

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[1] *Proc. Roy. Soc. Lond.*, vol. xxvi. pp. 441, 443, 1877.

The Trilobites offer another example of a group of invertebrates ever subject to modification, from the earliest known forms in the Cambrian to the last survivors in the Permian. They are thus especially fitted to aid the geologist, as each has distinctive features, and an abiding place of its own in geological time.

The above examples are all marine forms, and from their abundance, and wide distribution, both in time and space, are among the best of all witnesses in marking the succession and duration of changes in geological history.

If we turn now to the fresh-water Mollusca we find among them little evidence of change from the earliest Palæozoic forms to those still living, and can therefore expect little assistance from them in noting the succeeding periods during their life-history.

Among the fossil vertebrates the same law as to specialisation holds good. The value of particular groups as witnesses of geological changes depends largely on their own susceptibility to change, and this is equally true of single genera and species. There are indeed some primitive vertebrates, especially among the fishes, that appear to have changed little during their geological life. The genus *Lepidosteus* is a good illustration, and hence it is of limited value as evidence of what has taken place during its known geological history. Other fishes, however, are much better witnesses of the past.

The Reptiles as a class offer still better evidence of geological changes, and in many instances may be used to advantage in marking horizons. The great sub-class of Dinosaurs, from its beginning in the Triassic, shows marked changes of development throughout the whole of Mesozoic time. During the Cretaceous highly specialised forms made their appearance, and at the close of this period when all became extinct the last survivors were the strangest of all, reminding us, in their bizarre forms, of the last stages of the Ammonites, their contemporaries. The Crocodiles, too, show great changes during Mesozoic time, and are thus of much value in determining geological horizons. So, also, are the Pterodactyles and many other extinct reptiles, each according to the degree of specialisation attained.

The Mammals, however, are by far the most important class for marking geological time, as their changes and the high degree of their specialisation furnish the particular characters that are most useful to the geologist in distinguishing definite zones and the more limited divisions of the strata containing their remains. The few mammals known from the Trias are so peculiar that they can give only hints of what mammalian life then was, but in the Jurassic the many forms now known offer important testimony as to the different horizons in which their remains are found. This is true, also, of the known mammals from the Cretaceous; all are of value as witnesses of the past.

During Tertiary time, however, the enormous development of the class of mammals, their rapid changes, and, most important of all, the highly specialised characters they develop, offer by far the best evidence of even the smaller changes of climate and environment that mark their life history throughout. The Ungulates alone will answer the present purpose as an illustration, and even one group, the horses, will make clear the point I wish to emphasise.

Near the base of the Eocene the genus *Eohippus* is found, representing the oldest known members of the horse tribe. Higher up in the Eocene *Orohippus* occurs, and still higher is *Epihippus*, near the top of the Eocene. Again through the Miocene more genera of horses, *Mesohippus*, *Miohippus*, and others, follow in succession, and the line still continues in the Pliocene, when the modern genus *Equus* makes its appearance. Throughout this entire series definite horizons may be marked by the genera, and even by the species of these equine mammals, as there is a change from one stage to the other, both in the teeth and feet, so that every experienced palæontologist can distinguish even fragments of these remains, and thus identify the zones in which they occur.

This is true of every group of mammals, although not to an equal extent, so that in this class we have beyond question the best means of identifying the age of Tertiary strata by their fossil remains.

I have thus briefly pointed out some of the evidence on which a decision may be reached as to the value of the three different kinds of fossils—Plants, Invertebrates, and Vertebrates—in determining the age of strata. All evidence of this kind is of value, but it is the comparative value of each group that is the important point I wish to emphasise; and I have brought the matter before this Section of the Association in the hope that a better understanding on this question may be reached among geologists in the interest of the science to which we are all devoted.

2. *On Aggregate Deposits and their Relations to Zones.*
By Rev. J. F. Blake, *M.A.*, *F.G.S.*

An objection is sometimes made to the classification of strata in zones—by means of certain fossils—that cases are known in which the characterising fossils of more than one zone occur together in the same band of rock. It is sometimes replied to this, that a careful search will show that these fossils occur in their proper position even in this single band, the older type being found near the bottom and the younger near the top. Without denying the partial truth of this, the author regards these multizonal bands as having a special character which removes them from the ordinary type of deposit, for the subdivision of which the method of zones has been adopted. Zones are best observed in massive uniform deposits such as the Lias, Oxford Clay or Chalk, the formation of which has been continuous through the life-history periods, or hemeræ, of several species, which lie in the deposits in their natural position, as they would fall to the bottom, or lie there, at death, and be successively covered by subsequent portions of the deposit. These multizonal bands, however, do not differ from this type simply in the smaller amount of contemporaneous deposit, but show signs of being formed in a different way altogether. The fossils do not lie in a natural position, but often stand on end; they are not arranged in horizontal bands, but are confusedly mixed together; and they include broken fragments often of a *remanié* character, and these are in many cases of a considerable size. These peculiarities are considered by the author as evidence that the deposit was a tumultuous one, in which the material was drifted rapidly by strong currents in a horizontal direction. They are in fact the sweepings of the bottom of the sea from the places where the fossils originally lay, where they may or may not have been covered by deposit. It is for this reason that the fossils in them belong to various dates, the actual deposit itself being necessarily at least as young as the latest fossil it contains. The author therefore proposes to distinguish such deposits as AGGREGATES.

Whereas ordinary deposits, especially those in which zones are best marked, indicate tranquil deposition with the conditions remaining long unchanged, these aggregates indicate a marked change of conditions, and therefore in all probability the commencement of a new group of rocks. For this reason they are of considerable importance. The author's attention was specially directed to these aggregates in Russia, where they are found at the base of a series, by some considered to be a continuation of the underlying Jurassics, and by others to be the commencement of the Cretaceous rocks. There are, however, many instances of them in this country, as at Ilminster, where they are called Upper Lias; also the 'cephalopod-bed' of Gloucestershire, and the 'junction bed' above the Middle Lias on the Dorsetshire coast. Similar phenomena are reported from the base of the Cretaceous beds at Beer Head; and it is probable that the Faringdon sponge beds and the Neocomian nodule beds of Potton are of the same character. They are also reported from various localities in France and elsewhere on the Continent.

3. *The Geological Structure of the Malvern and Abberley Ranges.*
By Theodore Groom, *M.A.*, *D.Sc.*

In the district between Abberley and Bromesberrow two types of geological structure are distinguishable.

On the east is a comparatively undisturbed geological series ranging from the

Permian to the Lias, and on the west a greatly folded and faulted series ranging from the Archæan to the Old Red Sandstone, and capped in places by Coal-Measures and Permian.

Several divergent views as to the mode of origin of the Malvern Range have been offered.

Murchison maintained that the gneissic series was an igneous mass containing metamorphosed representatives of the Lower Palæozoic beds, into which it had been intruded.

Phillips regarded the range as a ridge of crystalline rocks against which the Palæozoic beds had been deposited on one side, and the New Red Sandstone at a later date on the other.

Holl later introduced the idea of overlap of the Palæozoic beds against a pre-Cambrian axis, and of post-Liassic faulting on the eastern side.

Still later Dr. Callaway suggested that the crystalline axis was a wedge of pre-Cambrian rocks faulted up through the neighbouring deposits.

The author's conclusions are as follows:—

The Triassic beds have in no sense been deposited against the side of the range, but are let down by a post-Liassic fault having a moderate downthrow, the Archæan and Palæozoic floor lying at a comparatively short distance below the surface on the eastern side of the range.

The Palæozoic beds, which are frequently extensively inverted along the whole length of the two ranges, appear to be everywhere separated from the gneissic series by a fault, which sometimes dips into the hill with a considerable hade.

This association of overfolds and thrust-planes suggests the forces concerned in the building of mountain ranges, and other evidence points in the same direction.

The axis of the Malvern Range is not merely a complex of schistose and igneous rocks, as hitherto supposed, but includes infolded and infaulted strips of Cambrian and Silurian rocks, running along lines (which in some cases mark thrust-planes) more or less parallel to the axis of the range.

The foliation of the schists in the neighbourhood of the most important of these lines of dislocation has a very marked relation to the direction of the line, and strongly suggests the formation of a secondary series of schists comparable with the 'Newer Schists' of the Scotch Highlands.

The structure of the range is to be explained on the assumption that we are dealing with the basal wreck of an old mountain chain, running generally north and south along the western border of the old 'Mercian Highlands,' the overfolding and over-faulting of which have taken place chiefly from the east.

The easterly extension of this old range lies buried beneath the Triassic deposits of the Vale of Gloucester.

4. *The Age of the Malvern and Abberley Ranges.*

By THEODORE GROOM, *M.A., D.Sc.*

The prevailing view that the Malverns formed an island or tract of land in the Cambrian and Silurian seas is based firstly on the supposed overlap, and, secondly, on lithology.

According to the author the appearance of overlap is simply due to faulting, and the Lower Cambrian beds, supposed to be absent from the area, are well represented, and their inclusion within the heart of the gneissic series, together with Silurian rocks, proves that the Cambrian and Silurian seas extended well over the site of the range.

The lithological resemblance between the Cambrian and Silurian pebbles and crystalline rocks of the range is not complete, and is best explained on the assumption that they have been derived from a neighbouring tract of land containing types of rock similar to those now exposed in the Archæan series of the Malverns, and of other Midland tracts.

The geological structure, moreover, proves the elevation of the Malvern axis to be due to Upper Palæozoic and later movements.

The age of the range is fixed by the circumstance that comparatively undisturbed

Permian and newer Coal-Measures rest unconformably on overturned Silurian, Old Red Sandstone, and older Coal-Measures.

The folds of the Malvern and Abberley Hills are connected with those seen in the Woolhope, May Hill, Usk, and Tortworth districts, and with those of the Forest of Dean, South Wales and Bristol Coal-field; and the author concludes that these folds, together with those of other parts of the British Isles, belong to the Great Hercynian system of mountains formed towards the close of the Carboniferous period.

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5. *On the Probable Source of the Upper Felsitic Lava of Snowdon.*
By J. R. DAKYNS, *M.A.*

Between Glaslyn and Bwlch Goch, as the lowest part of the ridge between Crib Goch and the top of Crib y Ddysgl is called, a mass of felstone rises like a wall through the beds of the calcareous ashy series. The trend of the dyke is E.N.E. The best section is along the N.W. face, where the felstone is clearly seen standing as a wall against the truncated edges of the calcareous ashy beds. The felstone shows *lines of flow parallel to its side*, and in some places is rudely columnar, *the axes of the prisms being perpendicular to the side of the dyke.* It is owing to this arrangement of the columns, and of the lines of flow, that I consider the rock to be a dyke. I call it a dyke because of the straightness of its sides; but it is rather a boss than a dyke, as, while it is two hundred yards wide, it is only about three or four hundred yards long. The rock is not like any of the Lower Snowdonian felsites occurring in the immediate neighbourhood, but it is decidedly like the upper felstone, which forms outliers on Crib Goch and Crib y Ddysgl. It seems to me that we have here the source of the upper felsitic lava of the Snowdon district. The boss is a plug of rock consolidated in and filling up the orifice through which the upper lava flowed to the surface.

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6. *On the Occurrence of Arenig Shales beneath the Carboniferous Rocks at the Menai Bridge.* *By* EDWARD GREENLY.

On the Carnarvonshire side of the Menai Straits, a little west of the suspension bridge, some dark shales have been found for a short distance along the shore, unconformably underlying the carboniferous sandstones. They have yielded Arenig Graptolites and Crustacea. On the Anglesey side, just opposite, pebbles of similar shales, also yielding Llandrilo-Arenig fossils, have been found in some glacial gravels. Taken in connection with other evidence it is inferred that these shales in all probability compose the floor of the Menai Straits east of the tubular bridge, and that some additional light is thereby thrown upon the nature and physical history of that hollow.

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7. *On an Uplift of Boulders at Llandegfan, Menai Straits.*
By EDWARD GREENLY.

A train of boulders of a massive grit, which occurs on the Anglesey shore of the Menai Straits at Garth Ferry, can be traced thence to the top of the hill at Twr y Felin, Llandegfan. The outcrops of the rock are almost entirely below the 50 feet contour, while the boulders are found in considerable numbers up to a height of 330 to 340 feet. The direction of carry is W.S.W. to W., and the distance in a straight line from Garth Ferry to the top of the hill is about a mile.

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8. *On the Comparative Dimensions of some Atoms.*
By W. L. ADDISON.

From the assumption that the attractive areas of the atoms behave as though they possessed the form of the crystals, so that the crystal of an element may be regarded as an assemblage of such forms, the author, continuing the inquiry on which he read a paper at the Toronto meeting, considers the ratio between the space occupied by such an assemblage and the volume of the interspaces between the atoms. By a comparison with the atomic volume he obtains thus a series of numbers which he regards as indicating the relative dimensions of the atoms of the following elements: C, Si, Pb, Th, Sn, P, As, Sb, Bi, S, I, Fe, Ni, Pd, Pt.

9. *Leadhillite in Ancient Lead Slags from the Mendip Hills.*

By L. J. SPENCER, *M.A., F.G.S.*

Lead ores have been worked in the Mendip Hills (East Somerset) ever since the time of the Romans; but during the present century operations have been chiefly confined to the reworking of the old waste heaps of slags and slimes. From these heaps upwards of 9,000 tons of lead were extracted during the ten years ending 1880. The material now being worked at Priddy has the appearance of a brown earth: it contains fragments of charcoal and limestone, and about 6 per cent. of lead as carbonate. Embedded here and there in this material are blocks consisting of devitrified slag, partially fused galena, and fragments of charcoal; and in the cavities numerous small crystals of cerussite ($PbCO_3$) and anglesite ($PbSO_4$) and, less frequently, of leadhillite.

Leadhillite has not been before observed under such conditions. In the Roman lead slags at Laurion, in Greece, which have been in contact with sea-water, Lacroix has noted the following secondary minerals: matlockite, penfieldite, laurionite, fiedlerite, phosgenite, cerussite, hydrocerussite, and anglesite.

The colourless crystals of Mendip leadhillite have, perpendicular to the perfect basal cleavage, an acute negative bisectrix with an optic axial angle in air of $2E = 72\frac{3}{4}°$; at a temperature of 97° C., $2E = 70\frac{1}{2}°$. The frequent twinning and the goniometric measurements (which are, however, not very good) are not inconsistent with the orthorhombic symmetry insisted upon by Miller. The basal planes of complicated twin crystals always give a single sharp reflected image, which is not the case with twin crystals of ordinary monosymmetric leadhillite. A few crystals are optically uniaxial.

There therefore seem to be three kinds of leadhillite, all of which are identical in outward appearance: (*a*) Monosymmetric, with the optic axial angle $2E = 20°$; (*b*) rhombohedral (?) and optically uniaxial (susannite); (*c*) orthorhombic, with $2E = 72\frac{3}{4}°$.

Before 1874 the formula for leadhillite was given as $PbSO_4.3PbCO_3$, and that now usually accepted is $PbSO_4.2PbCO_3.Pb(OH)_2$; but no two of the several analyses that have been made are in close agreement, and other formulæ have been proposed. Doubtless each of the above kinds has a definite chemical composition, and the variations shown by the different analyses are possibly due to the fact that two ((*a*) and (*b*) or (*b*) and (*c*)) of the three kinds may occur together in the same crystal, as observed by Bertrand and by myself in specimens from Leadhills. It will therefore be necessary to examine optically each fragment that is collected for future analyses of leadhillite.

10. *Supplementary List of British Minerals.*

By L. J. SPENCER, *M.A., F.G.S.*

During the forty years which have elapsed since the publication of Greg and Lettsom's 'Manual of the Mineralogy of Great Britain and Ireland' a considerable number of species, variety, and other names have been added to the list of minerals occurring in the British Isles. In 1858 Greg and Lettsom recognised 241 British species; but of these only 209 are given as numbered species by Dana in the sixth edition (1892) of his 'System of Mineralogy.' To this list may now be added 84 more, bringing the total number of British species up to 293, as compared with the total of 824 known mineral species recognised by Dana in 1892.

Owing to the difficulty, in some cases, of defining a mineral species, to the uncertainty of some of the determinations, and to the fact that a systematic search through the whole of the literature has not yet been made, these numbers can only be considered approximate.

Some of the most notable additions are of minerals which have been detected by the microscopical examination of rock-sections, *e.g.*, nephelite, nosean, and various felspars, pyroxenes, and amphiboles.

In the following list are added 113 other names which have been applied to British minerals; the species are distinguished by italics. The first observer and date have been added (in parenthesis) wherever possible; in other cases the earliest reference found is given:—

Abriachanite (Heddle, 1879).
Achroite (Collins, 1876).
Ægirite (Teall, 1888).
Aikinite (Museum Pract. Geol.).
Albertite (Morrison, 1884).
Alunogen (Smithe, 1882).
Amazon stone (Heddle, 1877).
Amblystegite (Judd, 1885).
Andesine (Heddle, 1877).
Andrewsite (Maskelyne, 1871).
Anorthite (Haughton, 1856).
Antigorite (Heddle, 1878).
Antimony? (Garby, 1848).
Atacamite (Church, 1865).
Balvraidite (Heddle, 1880).
Baricalcite (Breithaupt, 1841).
Barytocelestite (Collie, 1878).
Bastite.
Bathvillite (Williams, 1863).
Bauxite (Sutherland, 1870).
Bayldonite (Church, 1865).
Beekite.
Beraunite (Greg, 1860).
Bhreckite (Heddle, 1879).
Botallackite (Church, 1865).
Bowlingite (Hannay, 1877).
Braunite? (Collins, 1871).
Bruiachite (Macadam, 1886).
Bytownite (Teall, 1884).
Cantonite (Davies, 1877).
Cathkinite (Glen and Young, 1882).
Celadonite (Heddle, 1879).
Centrallassite (How, 1878).
Chalcosiderite (Maskelyne, 1875).
Chenevixite (Adam, 1866).
Chloritoid (Heddle, 1879).
Chloropal (Church, 1866).
Chlorophyllite (Heddle, 1882).
Chrome-diopside (Teall, 1888).
Chrysoberyl (Haughton, 1856).
Chrysotile.
Churchite (Church, 1865).
Cleavelandite (Heddle, 1877).
Clinochlore (British Museum).
Cloustonite (Heddle, 1880).
Coccolite (Heddle, 1877).
Collyrite (Gladstone, 1862).
Cotterite (Harkness, 1878).
Craigtonite (Heddle, 1882).
Crocidolite (Heddle, 1879).
Cryptolite (Church, 1872).
Danalite (Miers and Prior, 1892).
Daphnite (Tschermak, 1891).
Delessite (Heddle, 1879).
Demidoffite (Greg, 1860).
Descloizite (Frenzel, 1875).
Devilline (Pisani, 1864).
Dolianite (Des Cloizeaux, 1862).
Dudgeonite (Heddle, 1889).
Dufrenite (Kinch and Butler, 1886).
Duporthite (Collins, 1877).
Edenite (Heddle, 1878).
Electrum (Forbes, 1867).
Ellonite (Heddle, 1882).
Enstatite.
Enysite (Collins, 1876).
Eosite (Schrauf, 1871).
Eulytite (Collins, 1881).
Evansite (Woodward, 1884).
Ferrite (Heddle, 1882).
Fibrolite (Heddle, 1882).
Fichtelite (Macadam, 1889).
Freieslebenite? (Museum Pract. Geol.).
Funkite (Heddle, 1882).
Genthite (Heddle, 1878).
Gersdorffite (Forbes, 1868).
Gigantolite (Heddle, 1882).
Glaucophane (Blake, 1888).
Graminite (Collins, 1877).
Grastite (Heddle, 1878).
Grossular (Heddle, 1878).
Grünlingite (Muthmann & Schröder, 1897).
Halloysite (Heddle, 1882).
Haughtonite (Heddle, 1879).
Hausmannite (Goodchild, 1875).
Henwoodite (Collins, 1876).
Hibbertite (Heddle, 1878).
Hisingerite (Church, 1870).
Hovite (Gladstone, 1862).
Hullite (Hardman, 1878).
Hydrated labradorite (Heddle, 1880).
Hydrocerussite (Heddle, 1889).
Hydrophilite (Dana, 1892).
Hydroplumbite (Heddle, 1889).
Hydrozincite (Goodchild, 1883).
Iddingsite? (Arnold-Bemrose, 1894).
Igelströmite (Heddle, 1878).
Inverarite (Heddle, 1883).
Jarrowite (Lebour, 1887).
Johannite? (Garby, 1848).
Langite (Maskelyne, 1864).
Latrobite (Heddle, 1877).

Lepidomelane (Haughton, 1859).
Lettsomite (British Museum).
Leuchtenbergite (Glen and Young, 1876).
Leucoxene (Geikie, 1879).
Limnite (Church, 1865).
Linnæite (Terrill & Des Cloizeaux, 1880).
Liskeardite (Maskelyne, 1878).
Loganite (Harkness, 1866).
Löllingite (Collins, 1871).
Ludlamite (Field, 1877).
Lussatite (Mallard, 1890).
Lyellite (Maskelyne, 1864).
Marmolite (Heddle, 1878).
Martite (Heddle, 1882).
Massicot ? (Collins, 1871).
Melanite (Teall, 1892).
Microcline.
Mirabilite (Glen and Young, 1876).
Monazite (Miers, 1885).
Montmorillonite (Collins, 1878).
Mottramite (Roscoe, 1876).
Mountain silk, &c. (Heddle, 1879).
Necronite (Heddle, 1877).
Neotype (Breithaupt, 1841).
Nephelite (Allport, 1871).
Nephrite (Heddle, 1878).
Nosean (Allport, 1874).
Okenite (Glen and Young, 1876).
Oligoclase (Haughton, 1862).
Omphacite (Teall, 1891).
Orangite (Heddle, 1883).
Ottrelite (Hutchings, 1889).
Pargasite (Heddle, 1878).
Penninite (Heddle, 1878).
Penwithite (Collins, 1878).
Perthite (Heddle, 1883).
Phlogopite ? (Heddle, 1878).
Pickeringite (British Museum).
Picotite (Bonney, 1877).
Picrolite (Heddle, 1878).
Piedmontite (Dana, 1892).
Pihlite (Heddle, 1879).
Pilolite (Heddle, 1879).
Plumboaragonite (Collie, 1889).
Plumbogummite (Dana, 1850).
Plumbonacrite (Heddle, 1889).
Polybasite (Joy, 1860).
Polytelite (Forbes, 1867).
Prasilite (Thomson, 1840).
Protolithionite (Sandberger, 1885).
Proustite (British Museum).
Pseudo-hypersthene, &c. (Heddle, 1878).
Pseudophite (Heddle, 1879).
Pyroaurite (Heddle, 1878).
Pyrophyllite (Foster, 1876).
Pyrosclerite (Heddle, 1879).
Reichite (Breithaupt, 1865).
Restormelite (Church, 1870).
Rhabdophane (Lettsom, 1878).
Riebeckite (Harker, 1888).
Rock silk, &c. (Heddle, 1879).
Rubislite (Heddle, 1879).
Sanidine.
Scapolite (Ormerod, 1869).
Schraufite ? (Thomson, 1887).
Schrötterite (Dana, 1868).
Senarmontite (Davies, 1867).
Sericite.
Spangolite (Miers, 1893).
Spessartite (Heddle, 1878).
Stephanite (Davies, 1866).
Tallingite (Church, 1865).
Tavistockite (Church, 1865).
Thorite (Heddle, 1883).
Tobermorite (Heddle, 1880).
Totaigite (Heddle, 1878).
Tridymite (Lasaulx, 1876).
Turgite (Heddle, 1882).
Tyreeite (Heddle, 1881).
Uigite (Heddle, 1856).
Uralite.
Valentinite (Hall, 1868).
Vauquelinite (Davies, 1877).
Vermiculite (Parke, 1877).
Voltzite (Dana, 1868).
Walkerite (Heddle, 1880).
Waringtonite (Maskelyne, 1864).
Wicklowite (D'Achiardi, 1883).
Willemite (Glen and Young, 1876).
Wittichenite ? (Collins, 1871).
Woodwardite (Church, 1866).
Xantholite (Heddle, 1879).
Xanthosiderite (Haughton, 1866).
Xonaltite (Heddle, 1882).
Zeunerite (Weisbach, 1872).

11. *On the Age and Origin of the Granite of Dartmoor, and its Relations to the Adjoining Strata.* *By* ALEXANDER SOMERVAIL.

The object of this paper is to furnish proof that the true age of the Dartmoor granite, and most probably of the bosses of Cornwall, is referable to an interval or period of time between the Lower and Upper Culm or Carboniferous system.

The author regards the proofs advanced by De la Beche and others, up to this interval, as decisive, but thinks there is no evidence to support the post-Carboniferous or Permian Age of the granite.

In certain localities in the south of Devon there are conglomerates which contain fragments of the Radiolarian cherts and other Lower Culm rocks. These fragments conclusively prove that the Lower Culm had been elevated from a deep sea, and worn down to supply materials for the formation of the conglomerates.

These conglomerates, for certain reasons urged, undoubtedly belong to the Upper Culm, and seem to rest unconformably on the lower members, or even on the Devonian, thus marking a great interval.

The Lower Culm during its deposition and elevation was accompanied with igneous action, resulting in basic products which occupied a line running through what is now the centre of Dartmoor.

At the close of this interval great acid products rose up through this old line of volcanic action, resulting in the great masses of granite. These granite masses, especially that which forms Dartmoor in its upper and outer portions, may have consisted of products of a trachytic nature, and formed like the Domite Puys of Central France.

The Lower Culm rocks show the effects of great movements, cleavage structure, &c.

The conglomerates are but little disturbed, showing no signs of the previous great movements which affected the Lower Culm.

The interval between both is considered sufficient for the formation of the granite.

The Devonian and Lower Culm strata had been folded and the strike determined before the protrusion of the granite, as is clearly shown by the disposition and relations of these strata to the granite.

The alleged fragments of granite in the Permian breccias accord better with the inter-Culm than with the post-Culm or pre-Triassic age of the granite.

The conglomerates contain much arkose matter, quartz, felspar, mica, &c., in abundance, which would be difficult to account for if derived from the ordinary Devonian and Lower Culm strata of the adjoining area.

12. *Report on Fossil Phyllopoda.*—See Reports, p. 519.

13. *Report on Life-zones in the British Carboniferous Rocks.* See Reports, p. 529.

SATURDAY, SEPTEMBER 10.

The Section did not meet.

MONDAY, SEPTEMBER 12.

The following Papers and Report were read:—

1. *On the Relation and Extension of the Franco-Belgian Coal-field to that of Kent and Somerset. By* R. ETHERIDGE, *F.R.S.*

2. *The Laws of Climatic Evolution. By* MARSDEN MANSON, *C.E., Ph.D.*

The prime object of this paper is to formulate the laws of climatic evolution. In its entirety this problem is one of the most far-reaching and grandest in geological physics, embracing principles and laws applicable to other planets. After presenting these laws, the author pointed out that in consequence of them a hot spheroid rotating in space and revolving about a central sun, and holding fluids of similar properties to water and air within the sphere of its control, must pass through a series of uniform climates at sea level, gradually decreasing in temperature and terminating in an ice age; that this age must be succeeded by a zonal distribution of climates gradually increasing in temperature and extent.

The conclusions reached were: (1) that in the case of the earth zonal distribution of climates was inaugurated at the culmination of the ice age, and is gradually increasing in temperature and extent by the trapping of solar energy in the lower regions of the atmosphere, and that this rise has a moderate limit; (2) that the ice age was unique and due to the physical properties of water and air, and to the difference in specific heat of land and water; and (3) that prior to the ice age local formation of glaciers could occur at any latitude and period.

It was pointed out that Jupiter is apparently in a condition through which the earth has passed; and that Mars is apparently in a condition towards which present climatic evolution is tending.

3. *On the Sub-oceanic Physical Features of the North Atlantic.*
By Professor EDWARD HULL, *LL.D., F.R.S., F.G.S.*

The remarkable results arrived at by Professor Spencer and other American geologists regarding the sub-oceanic physical features of the Atlantic seaboard and the West Indian Islands induced the author to undertake a similar series of investigations along the eastern coast of the North Atlantic by the aid of soundings of the Admiralty Charts. These investigations extend from the neighbourhood of Rockall (lat. 57° 30′ N.) as far south as Cape St. Vincent, a distance of about 1,500 English miles, with a coast-line of about 2,000 miles, and were determined by tracing a series of contour, or isobathic, lines on the charts. The contours chiefly employed were those of 100, 250, 500, 750, 1,000, 1,200, and 1,500 fathoms. The features determined were as follows:—

1. The British and Continental platform, long since known under the name of 'the 100-fathom platform,' extends for variable distances outwards to the 100-fathom contour; but the author has found that this contour by no means represents the physical limit of the platform, as the seaward margin is formed by the abrupt descent of the sea-floor at depths varying, according to the position, from 100 fathoms at the Vidal Bank off the coast of Scotland, to the 250-fathom contour off the coast of Ireland in lat. 53° N. Off the coast of Spain the platform generally coincides with the 200-fathom contour. The platform thus defined is frequently indented by deep bays and traversed by old river channels, one of the most remarkable of which is 'the Hurd Deep' in the English Channel, traceable for 70 miles on the chart, and descending to a depth of 60 fathoms, or about 25 fathoms below the general level of the platform at this part. The platform all through has a floor of gravel, sand, and clay, with shells; and off the English coast has been described by Mr. Godwin-Austen in his paper on 'The Valley of the English Channel.'[1]

2. The second important feature indicated by the isobathic contours may be designated 'The Grand Escarpment,' along which the platform above described breaks off seawards. This escarpment is traceable from off Rockall and the Outer Hebrides, between which there is a deep bay, southwards to Cape St. Vincent. It follows the coast of the Bay of Biscay, at distances varying from 100 miles off the western coast to 20 or 30 miles off the southern coast. This great escarpment, about 2,000 miles long from north to south, has nothing comparable with it as regards magnitude in the British Isles and Europe. It is limited upwards by the 100 to 250 fathom contours, and downwards by those of 1,200 to 1,500 fathoms, thus giving an altitude (regarded from the point of view of having been once a land feature) of over 6,000 to 7,000 feet, according to locality. The base of the escarpment can be clearly determined at several points, as, for example, north of the Porcupine Bank (lat. 54° N.) and at the embouchure of the old cañon of the river Adour,

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[1] *Quart. Journ. Geol. Soc.*, vol. vi. (1849).

where it opens out on the floor of the deep ocean at a depth of about 1,500 fathoms. The slope of the escarpment varies considerably, but is occasionally almost precipitous, as, for example, off Cape Ortegal. From its base stretches the gently sloping floor of the abyssal ocean formed of foraminiferal ooze, as determined by Dr. G. C. Wallich and the 'Challenger' Expedition; thus the escarpment serves to separate the region of the calcareous floor from that of the platform composed of mechanically constituted materials. That it was formerly a land feature is proved by the presence of river channels and deep ravines or cañons once connected with the streams which drain the adjoining lands.

3. *Submerged River Channels and Cañons.*—By means of the soundings the courses of several rivers can be clearly traced, commencing at or near the shores of the neighbouring lands, and generally becoming more determinate as they approach the edge of the grand escarpment, through which they descend between precipitous walls of rock, some thousands of feet in depth, towards the floor of the abyssal ocean. Amongst those especially remarkable are the channels which drained the Irish Sea and English Channel, the positions of which have been indicated by several observers, including Mr. Godwin-Austen, Prof. Rupert Jones, Prof. Boyd Dawkins, and Mr. Jukes-Browne; but it does not appear that they recognised the fact that they are traceable down to depths of over 1,000 fathoms where they cut through the great escarpment. Besides the channels of some British rivers, those of the Loire, the Adour, Las Cubas, the Douro, and Tagus are very clearly defined, as the contours are traceable for miles inwards from the margin of the escarpment, indicating cañons of great depth, that of the Adour being traceable from the mouth of the existing river to its opening on to the floor of the deep ocean at a distance of 60 miles and a depth of 1,500 fathoms.[1] In some cases the rivers have had double channels when crossing the escarpment.

4. *Sea-stacks and Isolated Rocks.*—In addition to the above features, instances occur of huge sea-stacks or isolated bosses of rock rising from very deep water. One of these occurs off the north coast of Spain, and has an altitude of over 5,000 feet. In general form it was similar to the great bosses which rise from the waters on the coast of Scotland, such as the 'Bass Rock,' 'Rock of Dumbarton Castle,' and 'Ailsa Craig,' but was vastly greater in dimensions than any of these. Unfortunately we are unable by means of soundings to determine the composition of such masses, but they are probably formed of some excessively hard material, such as felstone, basalt, or other volcanic rock able to resist the assaults of the ocean waves for a longer period than the adjoining masses.

General Conclusion.—It will be evident that the features above described—the submarine escarpments and river channels—must have been formed, the one by wave action along rising or subsiding land surfaces, and the other by river erosion during a period of emergence of the whole region. It is only under sub-aërial conditions that such escarpments and river channels could have been formed; hence we are driven to the conclusion that the eastern side of the North Atlantic was upraised to the extent of 9,000 or 10,000 feet at a very recent period. This deduction is in harmony with that arrived at by Spencer, Upham, and other American geologists, and forces us to the conclusion that the whole area of the North Atlantic was a land surface to the depth of 10,000 feet at a very recent period. The author has pointed out how such an uprising of the lands must have affected the climatical conditions, resulting in a general lowering of the temperature; and in connection with the alteration in the course and temperature of the 'Gulf Stream' must have brought about conditions over the northern hemisphere such as those which are inferred to have been in force during the Pleistocene or Glacial period.[2]

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[1] M. Elisée Réclus has recognised this profound cañon, but is altogether at a loss to account for its origin.

[2] 'Another Possible Cause of the Glacial Epoch,' *Trans. Victoria Institute* (1898).

4. *The Eastern Margin of the North Atlantic Basin.*
By W. H. Hudleston, *F.R.S.*

Definition of the Subject.—Importance of oceanography in a geological sense. The submerged continental shelf, the 'edge,' the suboceanic continental slope, and the abyssal flat. The suboceanic continental slopes are the true margins of the several oceans. Limit of region dealt with in the paper from the Polar Ocean to about the 30th parallel of N. latitude. The suboceanic slope has sometimes been described as a 'submerged bank,' a 'terrace,' or an 'escarpment;' these terms, it is believed, are in many cases misleading. Remarks of Professor Milne on the tectonic importance of the suboceanic continental slope; he calculates that one-half of the earthquake shocks occurring throughout the world have their origin in these slopes, especially towards the base; his division into *seismic and non-seismic* districts.

Authorities for the Line Selected.—Allowing for sinuosities and for the easterly extension beyond Spitzbergen, this marginal line is not less than 5,000 miles. The principal authorities are Nansen's paper 'On Some Results of the Norwegian Arctic Expedition,' Mohn's work 'On the Norwegian North Atlantic Expedition,' Bartholomew's 'Physical Chart of the North Polar Regions,' and, lastly, several of the British Admiralty charts from Shetland to Gibraltar.

Descriptive and Hypothetical.—Section 1. *Arctic and Sub-Arctic.* Hydrographical details of the marginal line of the North Polar Ocean (outside Franz Josef Land and Spitzbergen) and of the Norwegian Atlantic are given. As a whole, so far as is known, the marginal slopes appear to be less steep than in the British-Biscayan region.

Discussion on the geological bearing of these details. It is contended that the North Atlantic, the Norwegian Atlantic, and such portions of the North Polar Ocean as have yet been sounded belong to one and the same great geosynclinal depression, which has locally been interrupted by volcanic extravasation. These facts serve to remind us of the two principal schools of geographical evolution, and of the theories relating to the permanence or non-permanence of the major features of the earth's crust. The arguments for and against permanence, both generally, and in reference to this particular region. It is suggested that a considerable amount of change throughout geological time may have taken place on the margins of the great oceans without materially affecting the great ocean basins themselves. In this way the crust of the earth still retains traces of its congenital features in the great ocean depths, and also in the position of the chief continental areas. Lord Kelvin's view that continents and ocean depths were due to heterogeneousness of composition in different parts of the liquid which constituted the earth's surface before solidification; from this heterogeneousness, he considers that the irregularities of the present surface followed as a dynamical necessity.

Section 2. *The Icelandic Shallows.*—Here the volcanic masses of Iceland and Færoe with their submarine attachments have produced a marked effect on the depths of the ocean. The Norwegian Atlantic connects with the main Atlantic by three channels; minimum depth in the Færoe-Shetland or Lightning Channel 319 fathoms; so that a little over 1,900 feet uprise is required to effect a land connection with Iceland and South-east Greenland. (N.B.—There is some difference in the maps on this point.) The suboceanic continental slope may be traced along the south-east side of this channel, though the steepest declivity is only 2½°; thence along the Vidal Bank to the Porcupine Ridge, off the coast of Connaught.

Former land connection with Iceland and Greenland required by the biologists. The views of Professor Spencer as to epeirogenic uplift on this side of the Atlantic.

Section 3. *The British-Biscayan Region.*—Hydrographical details between the South of Ireland and Ushant. Great width of the submerged continental shelf or 100-fathom platform in this quarter. Increased steepness of the suboceanic continental slope as the depths of the Bay of Biscay are approached. Irregularity of the contours in places; an incline of 6° to be taken as representing the steeper averages on the French side. Hydrography of the 'Fosse de Cap Breton,' of the deep channel off Bilbao, and of parts of the north coast of Spain.

Criticism of some of Professor Hull's hypotheses with respect to this region.

5. *The Great Earthquake of* 1897. *By* R. D. Oldham.

6. *Report on the Pleistocene Flora and Fauna of Canada.*

See Reports, p. 522.

7. *On Worked Flints from Glacial Deposits of Cheshire and the Isle of Man. By* J. Lomas, *A.R.C.S., F.G.S., Pres. Liverpool Geol. Soc.*

Flints are not common in the glacial deposits of N.W. England. In one or two places in the Wirral, however, and in the Isle of Man, they are fairly plentiful. Sometimes they occur in the Boulder Clay, but more frequently in Glacial Sands and Gravels.

Some of the flints collected in these localities show undoubted signs of human workmanship.

Prenton, Birkenhead.—The flints exhibited were collected from a recent excavation near Mount House. Soft Bunter is seen on the S. and W. faces overlaid by glacial sands. Between the two lies a bed of gravel containing small Lake District and Scotch erratics up to 6 in. diameter, along with broken Triassic rocks, clay galls, and marine shells. In this gravel most of the flints have been found. Others occur in the overlying sand, which also contains erratics and shell fragments. Similar sand occurs at many places in the immediate neighbourhood, and is usually overlaid by Boulder Clay.

Spital Sandpit.—False bedded clean sand is seen, containing gravel and rolled clay galls, overlaid by tough Boulder Clay. The flints occur both in the gravel and Boulder Clay.

Capenhurst.—Flints collected from gravel bands and clay in old sandpit opposite church.

Mollington, near Chester.—Large sandpit, near high road, contains very little gravel, and the flints mostly occur in the Boulder Clay which caps the section.

Cliffs, N. of Ramsey, Isle of Man.—Glacial deposits in north of island well exposed in the fine cliffs which extend from Ramsey almost to the Point of Ayre. Near Ramsey, sands and gravels predominate, and these get successively more and more clayey towards the N.

In collecting the flints the author took great care to separate those found in the talus slopes from those actually in the clays and gravels. The flints were exhibited.

8. *The Glacial Sections at Moel Trifaen.*
By E. Greenly, *F.G.S., and* A. B. Badger.

Attention is called to the impending destruction of the best and clearest part of the Moel Trifaen sections, and some lantern-slides shown to illustrate especially the nature of the rock surface below the gravels and the relation of these to the Boulder Clay. The terminal curvature in the slates is dwelt upon. This is well marked, and is independent of the inclination of the surface, which does not exceed 3° to 4°. The laminæ are bent over in a southerly direction. The displaced laminæ pass up into a breccia of angular and sub-angular fragments of slates which underlies the gravels.

It is hoped that an effort will be made while yet there is time to preserve an adequate record, by photography and other means, of the phenomena displayed in this classical section.

9. *On some Dinosaurian Remains from the Oxford Clay of Northampton.* *By* C. W. ANDREWS.

TUESDAY, SEPTEMBER 13.

The following Papers and Reports were read:—

1. *Restoration by Charles Knight of the Extinct Vertebrates* Brontosaurus, Phenacodus, Coryphodon, Teleoceras. *By* Professor H. F. OSBORN.

2. *The Work of Encrusting Organisms in the Formation of Limestone.* *By* E. WETHERED.

3. *The Action of Waves and Tides on the Movement of Material on the Sea Coast.* *By* W. H. WHEELER, *M.Inst.C.E., Boston, Linc.*

The object of this paper is to show the relative effect of waves due to wind and tidal action on littoral drift.

It is pointed out that all cliffs that border the sea coast are doomed to erosion, and the material derived from their destruction, after being sorted and prepared by waves and tidal action, is conveyed to the depths of the sea.

The function of wind waves is to break down the cliffs, to sort the material displaced, and to reduce the larger rock fragments into sizes sufficiently small to be acted on by the tides, and to disperse material that has been collected in large masses by tidal action.

The function of the tides consists in raising the water of the ocean sufficiently high to enable the waves to attack the cliffs, in assisting in the grinding up of the reduced rock fragments by their perpetual oscillating motion until sufficiently reduced in size, and then in transporting them to the bed of the sea, the latter operation being effected either in solution, suspension, or rolling along the bottom.

It is shown that all material eroded from the cliffs is ultimately carried seaward, and that the sea yields nothing to the land. The only agents capable of transporting material of greater specific gravity than the water are the waves, and their action, until they break on the shore, is merely one of undulation; and therefore it is only the stones, shingle, or sand which lie shorewards of the point where the wave breaks that can be carried forward on to the beach. On the other hand, the slope of the beach being seawards, all material has a natural tendency to work downwards under the action of gravity, this downward action being aided by the undertow of the retiring shore waves.

Material eroded from the cliffs consists of rock fragments, boulders, sand, and alluvium. The alluvium, consisting of particles of sufficient minuteness to remain in suspension for a considerable time, is diffused by the waves over a very considerable distance, and is finally deposited in the deep part of the ocean; the sand is gradually worked down the beach by the action of the waves and tides, and is also spread over the sea bed, but nearer to the shore; the rock fragments are reduced to shingle small enough to be acted on by the tides, and in this condition are rolled up and down the beach and drifted along the coast until ground into particles sufficiently fine to be transported to the sea. Shingle is generally accumulated in banks in the zone lying between low water of neap tides and high water of spring tides, and travels along the coast in one given direction. The heaping up and travel of the shingle is due to tidal action. The effect of wind waves due to gales is principally destructive to shingle banks, cutting out and dispersing the material, the banks being restored by tidal action in calm weather and during off-shore winds. The action of waves due to wind is intermittent, variable in direction, and irregular. The travel of shingle, except when acted on by gales, is continuous, regular, and constant in direction. It is shown by a number of examples that the travel of shingle is not coincident either with the prevailing or predominant winds, but on a tidal coast the predominant drift is invariably in the same direction as that of the flood tide. The action of the tides in heaping up and drifting material is due to wave action. The rise and fall of the tide on the coast does not consist of a mere vertical rise and fall of the water, but of a continual oscillation. The crest of the tidal wave in the open sea, being in advance of that near the shore, results in an oblique lateral movement along the beach, and the advance of the water being checked by the shallow bed with which it comes in contact is reflected back, resulting in a series of small oscillations or waves which break when they reach the low-water line. These oscillations are ever present on the margin of the shore, even when the sea is calmest, and are never absent except when absorbed by larger waves due to gales. These tidal wavelets vary in height from 6 inches to 2 feet, and break on the shore at the rate of from ten to twenty a minute according to the rise of the tide and the slope of the beach. These wavelets, aided by the flood current, lift up and carry forward any coarse sand, loose stones, or other material with which they come in contact, and leave some portion of it stranded at the highest point to which the tide of the day reaches. The wavelets, besides lifting and transporting the shingle, brush upward the whole of the face of the bank, and gradually raise it above the line of high water. It is shown that, though these waves are small, they by their weight and velocity develop sufficient force to move a large quantity of pebbles. A wave having a height of only a foot from trough to crest, giving a head of 6 inches, and containing a volume of water equal to a weight of ·142 ton, has sufficient kinetic energy to raise 165 lbs. of pebbles a foot high. Allowing the weight of pebbles in water to be 100 lbs. to the cubic foot, each wave, if the whole of its energy be applied to the movement of the material, is capable of raising 660 pebbles 2 inches in diameter a foot; or, with fifteen waves to the minute, 9,900 pebbles a minute and 2,376,000 in a single tide, or a total weight of stone of 266·4 tons a foot high. This, however, is beyond the work actually done, as a portion of the energy of the wave is absorbed in friction. The above rough approximation of the power of the wavelets is sufficient to show the enormous power that is developed by tidal action day by day on the coast, and the capability of the wavelets due to the tides for building up shingle banks and drifting the pebbles along the beach.

4. *Further Exploration of the Ty Newydd Cave, Tremeirchion, North Wales. By* Rev. G. C. H. Pollen, *S.J., F.G.S.*

In a paper read before the Geological Society on December 15, 1897,[1] the author gave the results of the exploration of 60 feet from the old quarry. The work has now been extended to 150 feet in this direction. In the upper portion a stalagmite floor has been found *in situ*, completely sealing up the local gravels. Over this were found 5 feet of clay with broken limestone, which is all that is left to represent the strata which previously formed the roof of the cave. The whole is now overlaid with boulder clay, containing many specimens of northern and western drift, with striated stones of more local origin. No trace of erratics or of glaciated stones have been found in the lower cave materials.

The cave has also been traced for 55 feet across the floor of the quarry where it re-enters the rock, running in the direction of the gully which separates it from the Ffynnon Beuno and Cae Gwyn Caves. In the lowest gravel of this part a water-worn fragment of the molar of *Equus* was found. The following succession seems to be established for the contents of the cave:—

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[1] *Q.J.G.S.*, February, 1898, pp. 119–134, pl. viii.

A. Cave nearly filled by torrents with local gravel containing water-worn fragments of mammalian teeth.

B. Formation of stalagmite floor.

C. Last few yards of floor broken up and re-deposited further down the cave by floods, which completely filled lower portion with sand and clay.

D. Denudation of rock above, destroying roof of upper portion and depositing limestone *débris* on floor in a matrix of clay.

E. Introduction of striated stones and northern and western erratics, which are deposited as one bed over the hill-side.

5. *Further Exploration of the Fermanagh Caves.*[1]

By THOMAS PLUNKETT, Enniskillen.

The original report above referred to having been drawn up and read by me at Dublin in 1878, and in which I stated that 'the explorations were suspended after the exploration of F cave, as the probability is that none of the caves in this district will yield bones of extinct mammalia.'

I spent three summers exploring the caverns which penetrate the Carboniferous Limestone hills in Fermanagh, in which I found flint implements, bone, bronze, and iron pins, a large cinerary urn inverted over burnt human bones, human skulls, ancient hearths, &c., also quantities of the bones of the wild horse, red deer, long-snouted pig, ox and remains of other animals not extinct. Having explored a number of caves in this county previous to my reading the report referred to above, I came to the conclusion that remains of extinct mammalia were not likely to be found in this locality. Now, on the contrary, I am glad to be in a position to report that I have been fortunate in finding an entire cranium of what I believe is the great cave bear (*Ursus spelæus*) in one of the Knockmore caverns which penetrates a cliff not far from the caverns I formerly explored, and is a narrow cleft with vertical sides. The height of the cave is about 40 feet, and length 90 feet. When standing at the extreme end of this cleft-cavern one may observe at the top of one of the sides an opening which is evidently the end of a horizontal cave which runs at right angles into the top of the cave in question; a good deal of *débris* has been during heavy rains washed out of the higher cave down into the lower one; in this *débris*, the cave bear's head was found, and I have no doubt but, when explored, the higher cave will yield more remains of the skeleton of the bear and possibly other extinct animals.

I have commenced excavations on the top of the rock, and hope to find the upper or horizontal cavern (which cannot be reached from the narrow cave below) which formerly must have had an opening out to the surface of the ground, and probably has been filled up level with the surface for the protection of cattle.

I thought it well to have this find in Fermanagh recorded in the proceedings of the British Association, and I shall be happy to report to the Association next year the results of the cave digging which I am carrying on here at present.

6. *Report on Remains of the Irish Elk in the Isle of Man.*

See Reports, p. 548.

7. *Report on the Erratic Blocks of the British Isles.*—See Reports, p. 552.

8. *Report on Seismological Investigation.*—See Reports, p. 179.

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[1] See Report, 1878, pp. 183–185.

9. *Report on the Fauna of Caves near Singapore.*—See Reports, p. 571.

10. *Report on the Structure of a Coral Reef.*—See Reports, p. 556.

11. *Final Report on the Eurypterids of the Pentlands.*
See Reports, p. 557.

SECTION D.—ZOOLOGY (INCLUDING ANIMAL PHYSIOLOGY).

PRESIDENT OF THE SECTION.—W. F. R. WELDON, M.A., F.R.S., Professor of Comparative Anatomy and Zoology, University College, London.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

IN attempting to choose the subject of the address with which custom obliges your President to trouble you, I felt that I should have the best hope of interesting you if I decided to speak to you on the subject most interesting to myself. I therefore propose to discuss, as well as I can, the principal objections which are urged against the theory of Natural Selection, and to describe the way in which I think these objections may be met.

The theory of Natural Selection is a theory of the importance of differences between individual animals. In the form in which Darwin stated it, the theory asserts that the smallest observable variation may affect an animal's chance of survival, and it further asserts that the magnitude of such variations, and the frequency with which they occur, is governed by the law of chance.

Three principal objections are constantly brought forward against this theory. The first is that the species of animals which we know fall into orderly series, and that purely fortuitous variations cannot be supposed to afford opportunity for the selection of such orderly series; so that many persons feel that if the existing animals are the result of selection among the variable offspring of ancestral creatures, the variations on which the process of Natural Selection had to act must have been produced by something which was not chance.

The second objection is that minute structural variations cannot in fact be supposed to affect the death-rate so much as the theory requires that they should. And it is especially urged that many of the characters by which species are distinguished appear to us so small and useless that they cannot be supposed to affect the chance of survival at all.

The third objection is that the process of evolution by Natural Selection is so slow that the time required for its operation is longer than the extreme limit of time given by estimates of the age of the earth.

Now the first of these three objections, the objection to fortuitous variation as the source of the material on which Natural Selection can act, is very largely due to a misunderstanding of the meaning of words. The meaning of the word Chance is so thoroughly misunderstood by a number of writers on evolution that I make no apology for asking you to consider what it does mean.

Consider a case of an event which happens by chance. Suppose I toss a penny, and let it fall on the table. You will agree that the face of the penny which looks upwards is determined by chance, and that with a symmetrical penny it is an even chance whether the 'head' face or the 'tail' face lies uppermost. For the moment, that is all one can say about the result. Now compare this with the statements we can make about other moving bodies. You will find it stated, in any almanac, that there will be a total eclipse of the moon on December 27, and that the eclipse will become total at Greenwich at 10.57 P.M.; and I imagine you will all feel sure, on reading that statement, that when December 27 comes the eclipse will occur; and it will become total at 10.57 P.M. It will not become total at 10.50 P.M., and it will not wait until 11.0 P.M. You will say, therefore, that eclipses of the moon do not occur by chance.

What is the difference between these two events, of which we say that one happens by chance, and the other does not? The difference is simply a difference of degree in our knowledge of the conditions. The laws of motion are as true of moving pence as they are of moving planets; but it happens that we know so much about the sun, and the earth, and the moon, that we know the circumstances which affect their relative positions very accurately indeed, so that we can predict within less than a minute the time at which the shadow of the earth will next fall upon the moon.

But the result of tossing a penny depends upon a very large number of things which we do not know. It depends on the shape and mass of the penny, its velocity and direction when it leaves one's hand, its rate of rotation, the distance of one's hand from the table, and so on. If we knew all these things before tossing the penny, we should be able to predict in each case what the result would be, and we should cease to regard pitch and toss as a game of chance.

As it is, all we know about these complicated conditions is that if we toss a penny for a number of times, the conditions which give 'heads' will occur about as often as the conditions which give 'tails.'

If you examine any event which occurs by chance, you will find that the fortuitous character of its occurrence always depends upon our ignorance concerning it.

If we know so little about a group of events that we cannot predict the result of a single observation, although we can predict the result of a long series of observations, we say that these events occur by chance. And this statement seems to me to contain the best definition of chance that can be offered.

If we use the word chance in this sense, we see at once that our knowledge of animal variations is precisely knowledge of the kind referred to in our definition of chance. We know with some certainty the average characters of many species of animals; but we do not know exactly the character of the next individual of these species we may happen to look at. So that in the present state of our knowledge it is *à priori* certain that the great majority of animal variations should occur by chance, in the sense in which we have used the phrase; and I will show you in a moment illustrations of the fact that they do so occur.

But before doing so, I would point out the difference between the sense in which we have used the word chance, and the sense in which it is used by many objectors to the theory of Natural Selection. Such epithets as *blind*, *lawless*, and the like, are constantly applied to chance; and a kind of antithesis is established between events which happen by chance, and those which happen in obedience to natural laws. In many German writings, especially, this antithesis between *Zufälligkeit* and *Gesetzmässigkeit* is strongly insisted upon, whenever organic variation is discussed.

This view of chance is not supported by experience; and indeed, if it could be shown that anything in human experience were absolutely lawless, if it could be shown that in any department of Nature similar conditions did not produce similar effects, the whole fabric of human knowledge would crumble into chaos, and all intellectual effort would be a profitless waste of time. There is not the slightest reason to believe that any such absolutely lawless phenomena do exist in Nature; so that we need pay no further attention to the writers who assume that chance is a lawless thing.

But if chance is a perfectly orderly and regular phenomenon, then the question, whether animal variations occur by chance or not, can be settled by direct observation. I will now show you one or two examples of events which undoubtedly occur by chance, and then compare these with one or two cases of organi variation.

As events which occur by chance, I have taken the results of tossing twelve dice. My wife has spent some time during the last two months in tossing dice for you, and I will ask you to look at the results.

Her first record gives the number of dice showing more than three points in each of 4,096 throws of twelve dice. There are, of course, six numbers on each of the dice; so that if all the dice were perfectly symmetrical and similar, the average number of dice with more than three points should be six in each throw of twelve. But dice are not symmetrical and similar. The points on the dice used were marked by little holes, scooped out of their faces; and the face with six such holes scooped out of it was opposite to the face with only one such hole: so that the face with one point was heavier than the face with six points; and therefore six was rather more likely to be uppermost than one. In the same way, two was opposite five; so that the five face was a little more likely to fall uppermost than the face with two points. Therefore, it is a little more likely that you will throw four, five, or six, in throwing dice, than it is that you will throw one, two, or three.

Accordingly, the average number of dice, in these 4,096 throws, which had more than three points, was not six, but 6·135.

To show you that this excess of high points was due to some permanent property of the dice, she threw these twelve dice another 4,096 times; and the average number of dice with more than three points was 6·139. A third series of trials gave an average of 6·104, and a fourth gave an average of 6·116.

You see that the difference between the highest and the lowest of these determinations is only about one-half per cent., so that the mean result of such a series of fortuitous events can be determined with great accuracy.

And just as the mean of the whole series can be determined, so we can know with considerable accuracy how often any possible deviation from the average result will occur. The degree of accuracy with which we can know this may be judged from Table I.

TABLE I.—*Frequency with which Dice showing more than three points were thrown in each of Four Series of Trials, the number of throws in each Series being* $2^{12} = 4{,}096$.

Number of Dice with more than 3 Points	Most Probable Frequency for Symmetrical Dice	Observed Frequencies			
		I.	II.	III.	IV.
12	1	0	1	0	1
11	12	11	13	8	14
10	66	71	86	61	66
9	220	257	246	241	241
8	495	536	540	513	586
7	792	847	836	856	861
6	924	948	913	948	866
5	792	731	750	802	728
4	495	430	446	420	474
3	220	198	198	182	204
2	66	60	55	51	67
1	12	7	12	13	6
0	1	0	0	1	0

You see that the results of the experiments agree fairly well with one another, and differ from the results most probable with symmetrical dice, in the way which the structure of the actual dice would lead one to expect. Throws which give seven, eight, or nine dice with more than three points occur too often, throws in which only two, three, or four dice have more than three points do not occur often enough. You see then that each of these results is orderly and regular, and that the four results agree very fairly among themselves, not only in the mean value of each of them, but in the magnitude and frequency of departures from the mean.

That they differ from the results which would probably be obtained with symmetrical and similar dice is only to be expected, because the dice used are neither symmetrical nor similar.

You notice that this table is very nearly symmetrical; the most frequent result is that which lies in the middle of the series of possible results; and the other frequencies would, with perfect dice, be distributed symmetrically on each side of it; so that with perfect dice one would be as likely to throw five dice out of twelve with more than three points as one would be to throw seven, and so on.

This symmetry in the distribution of the results is only found when the chance of the event occurring in one trial is even. The next table shows the result of 4,096 throws of twelve dice, in which sixes only were counted. The chance against throwing six with any one of the dice is of course five to one; so that in throwing twelve dice you are more likely to throw two sixes than to throw any other number. But you see that the chance of throwing only one six is very much greater than the chance of throwing three; the chance of throwing none is greater than the chance of throwing four, and while there is a chance of throwing five, six, or more, of course it is impossible to throw less than none at all; so that the diagram is all askew. You see that this time, as before, the frequency with which any number of sixes did actually occur was as near to the result most probably with perfect dice as the asymmetry of the actual dice allows one to expect.[1]

TABLE II.—*Frequency of Sixes in* 4,096 *throws of Twelve Dice.*

Number of Sixes	Most Probable Number with Symmetrical Dice	Number Observed
8	0·58	1
7	4·66	7
6	27·18	24
5	116·43	115
4	363·84	380
3	808·53	796
2	1211·44	1,181
1	1102·56	1,145
0	459·52	447

These results will be enough to show you how absurd is the attitude which so many writers have taken up towards chance when discussing animal variation. The assertion that organic variation occurs by chance is simply the assertion that it obeys a law of the same kind as that which expresses the orderly series of results we have just looked at.[2]

That is a matter which can be settled by direct observation. But in order to express the law of chance in such a way that we can apply it to animal variation, we must make use of a trick which mathematicians have invented for that purpose.

It is a well-known proposition in probability that the frequency with which one throws a given number of sixes in a series of trials with twelve dice is proportional to the proper term in the expansion of $(\frac{1}{6}+\frac{5}{6})^{12}$. The most probable numbers in this table were calculated by expanding this expression. But if I had wanted to show you the most probable result of experiments with 100 dice, I should not willingly have expanded $(\frac{1}{6}+\frac{5}{6})^{100}$. The labour would be too enormous.

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[1] It is unfortunate that I chose dice as instruments in these experiments. Dice are not only sensibly *asymmetrical*, but any ordinary dice are sensibly *dissimilar*; so that the result most probable with any actual dice is not given by a simple binomial expansion. The result theoretically most probable for the actual dice used could not be determined without very careful measurement of the dice themselves; and I was unable to attempt measures of the requisite accuracy. All that the records show, as they stand, is the amount of agreement between four successive observations of a fortuitous event.

[2] The law is not, however, identical in the two cases; see *infra.*

Then, again, suppose we are given a number of results, and are not told how many dice were used, how are we to find out the power to which we must raise $(\frac{1}{6}+\frac{5}{6})$, since this depends on the number of dice?

Before applying the law of chance to variations in which we cannot directly measure the number of contributory causes (the analogue of the number of dice), we must find some way out of these difficulties.

The way is shown by the diagram (fig. 1).

The rectangles in this diagram are proportional to the various terms of $(\frac{1}{2}+\frac{1}{2})^{12}$; and they represent the most probable result of counting the number of dice with more than three points in a series of trials with twelve dice. The heights of these rectangles were determined by expanding $(\frac{1}{2}+\frac{1}{2})^{12}$; but you notice the dotted curve which is drawn through the tops of them. The general slope of this curve is, you see, the same as the general slope of the series of rectangles; and the area of any strip of the curve which is bounded by the sides of a rectangle is very nearly indeed the same as that of the rectangle itself.

FIG. 1.

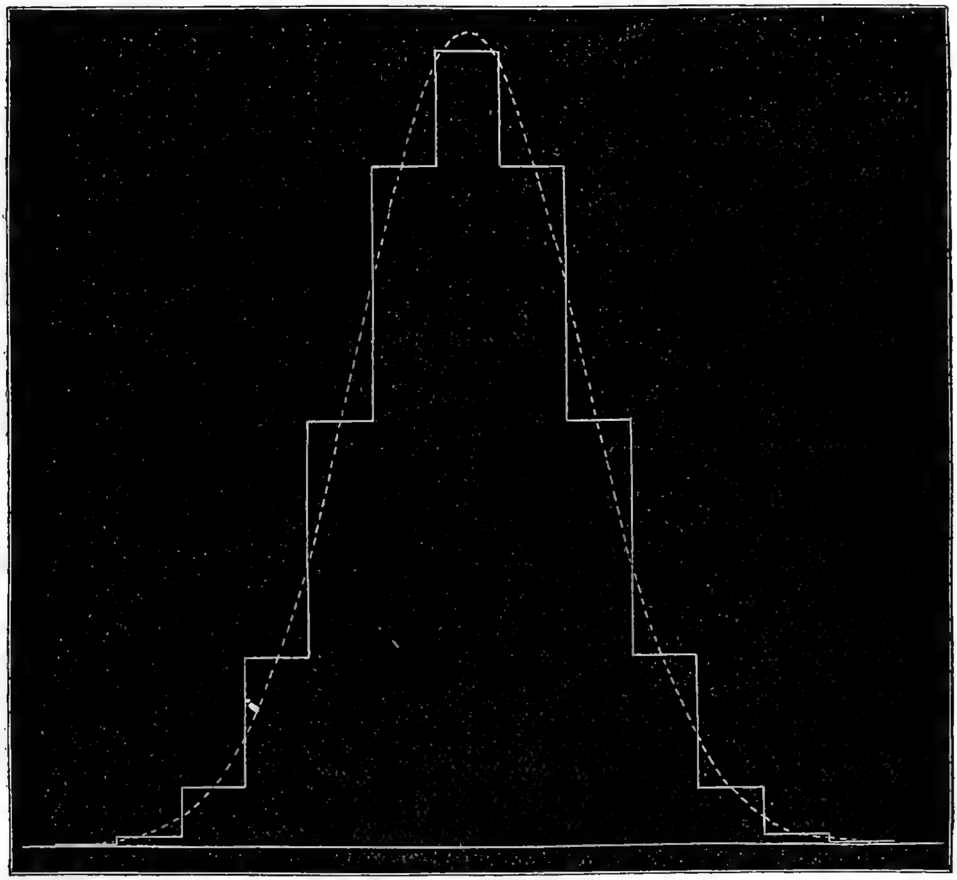

Diagram showing results of experiments with dice.

The constants upon which the shape of this curve depends are easily and quickly obtained from any series of observations; so that you can easily and quickly see whether a set of observed phenomena obeys the symmetrical law of chance or not.

A good many characters of animals do vary in this symmetrical way; and I show you one, which will always be historically interesting, because it was one of the principal characters used to illustrate Mr. Galton's invaluable applications of the law of chance to biological problems. That is the case of human stature. The diagram (fig. 2) shows the stature of 25,878 American recruits; and you see that the frequency with which each stature occurs is very close indeed to that indicated by the curve. So that variations in human stature do occur by chance, and they occur in such a way that variation in either direction is equally probable.

In cases where a variation in either direction is equally likely to occur, this symmetrical curve can be used to express the law of distribution of variations. And the great difficulty in applying the law of chance to the treatment of other cases was, until quite lately, that the way of expressing asymmetrical distributions by a similar curve was unknown; so that there was no obvious way of determining whether these asymmetrical distributions obeyed the law of chance or not.

The form of the curve, related to an asymmetrical distribution of chances, as the curve before you is related to symmetrical distributions, was first investigated by my friend and colleague Professor Karl Pearson. In 1895 Professor Pearson published an account of asymmetrical curves of this kind, and he showed the way in which these curves might be applied to practical statistics. He illustrated his remarkable memoir by showing that several cases of organic variation could be easily formulated by the method he described; and in this way he made it possible to apply the theory of chance to an enormous mass of material, which no one had previously been able to reduce to an orderly and intelligible form.

In this same memoir Professor Pearson dealt with another problem in the theory of chance, which has special importance in relation to biological statistics. It has doubtless occurred to many of you that the analogy between the complexity of the results obtained by tossing dice, and the complexity of events which determine the character of an animal body, is false in an important respect. For the events which determine the result, when we throw a dozen dice on the table, affect each of the dice separately; so that if we know that one of the dice shows six points, we have no more reason to suppose that another will show six points than we had before looking at the first.[1] But the events which determine the size or shape of an organ in an animal are probably not independent in this way. Probably when one event has happened, tending to increase the size of an arm or a leg in an embryo, it is more likely than it was before that other events will happen leading to increased size of this arm or leg. So that the chances of variation in the size of a limb would be represented by a law similar to that which expresses the result of throwing dice, but different from it. They would more nearly resemble the result of drawing cards out of a pack. Suppose you draw a card out of a pack. It is an even chance whether you draw a red card or a black one. Suppose you draw a red card, and keep it. The chance that your second card will be red is not so great as the chance that it will be black; because there are only twenty-five red cards and twenty-six black cards left in the pack.

Now Professor Pearson has shown how to deal with cases of this kind also; and how to determine, from the results of statistical observation, whether one is dealing with such cases or not.

I am no mathematician, and I do not dare even to praise the mathematical process by which this result was achieved. I will only say that it is experimentally justified by the fact that most statistics relating to organic variation are most accurately represented by the curve of frequency which Professor Pearson deduces for the case where the contributory causes are mutually inter-dependent.[2]

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[1] That is to say, if we know beforehand that the dice are symmetrical.

[2] Even the distribution of human stature, which has been so successfully treated by the older, so-called 'normal' curve, is more accurately represented by a curve of Professor Pearson's type; but in this case the difference between the two is so slight as to be inappreciable for all practical purposes; so that Mr. Galton's practice and Professor Pearson's theory are alike justified.

The first case of an asymmetrical distribution in animals which I ask you to look at is the frequency of variations in the size of part of the carapace of shore

FIG. 2.

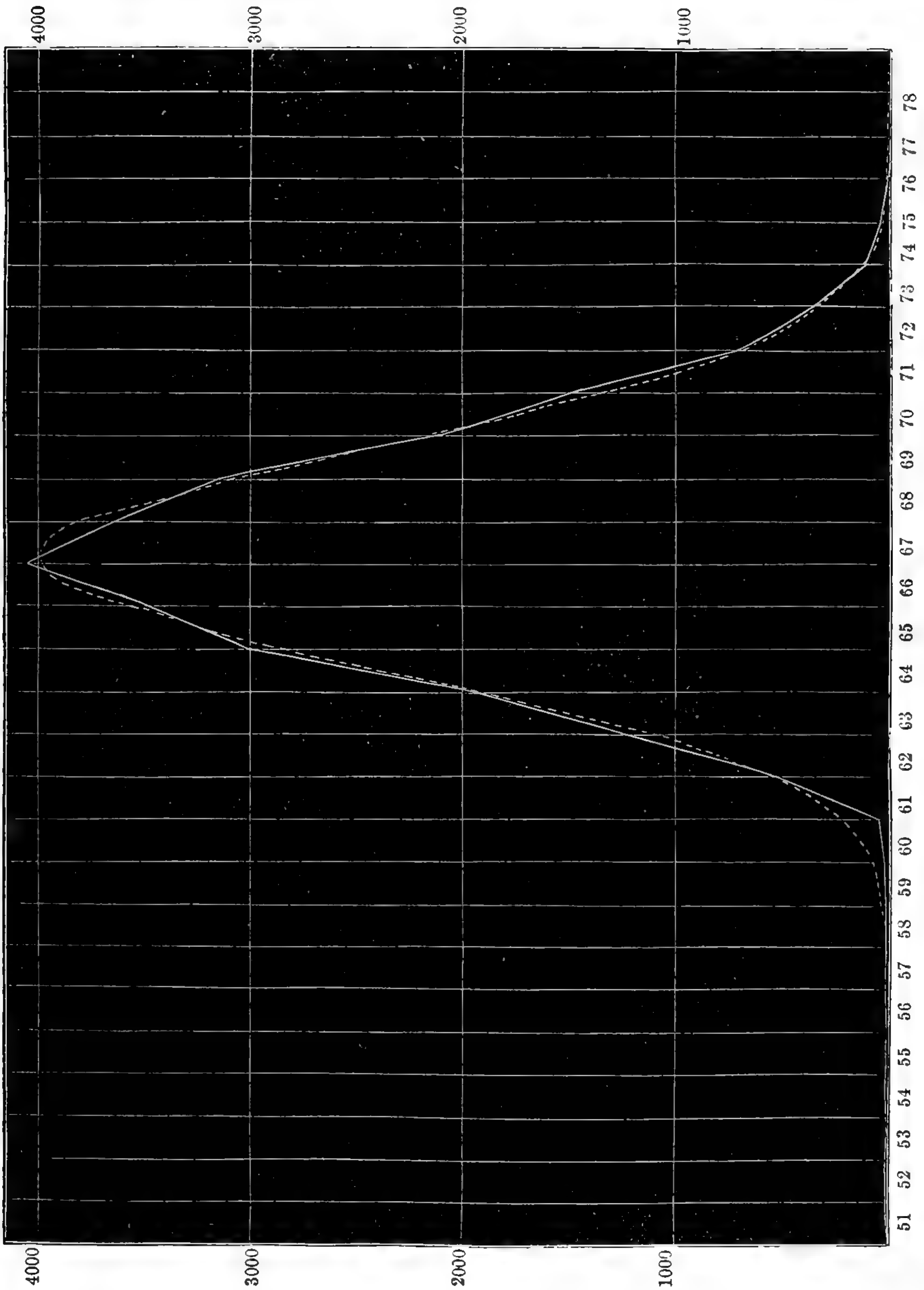

Diagram showing the height (in inches) of each of 25,878 American recruits.

crabs. The crabs measured were 999 females from the Bay of Naples. In this case the distribution of variations (see fig. 3) is very nearly symmetrical, and in an account of these crabs which I wrote before Professor Pearson's memoir was published I treated them as symmetrical. The curve actually drawn on the diagram is one constructed by Professor Pearson himself from the data given by my measurements of the crabs, and it fits the observations very sensibly better than the symmetrical curve. So that this dimension of a crab's carapace does vary by chance, but the chance of a given deviation from the mean length is not quite the same in both directions.

Now, admitting for the moment that these differences in the length of a part of the crab's carapace can affect the crab's chances of survival, you see that natural selection has abundant material on which to work. The production of this regular series of deviations from the mean length of the antero-lateral margin is as definite a character of the crabs as the mean itself; and in every generation a series of deviations from the mean is regularly produced, according to a law which we can learn if we choose to learn it.

FIG. 3.

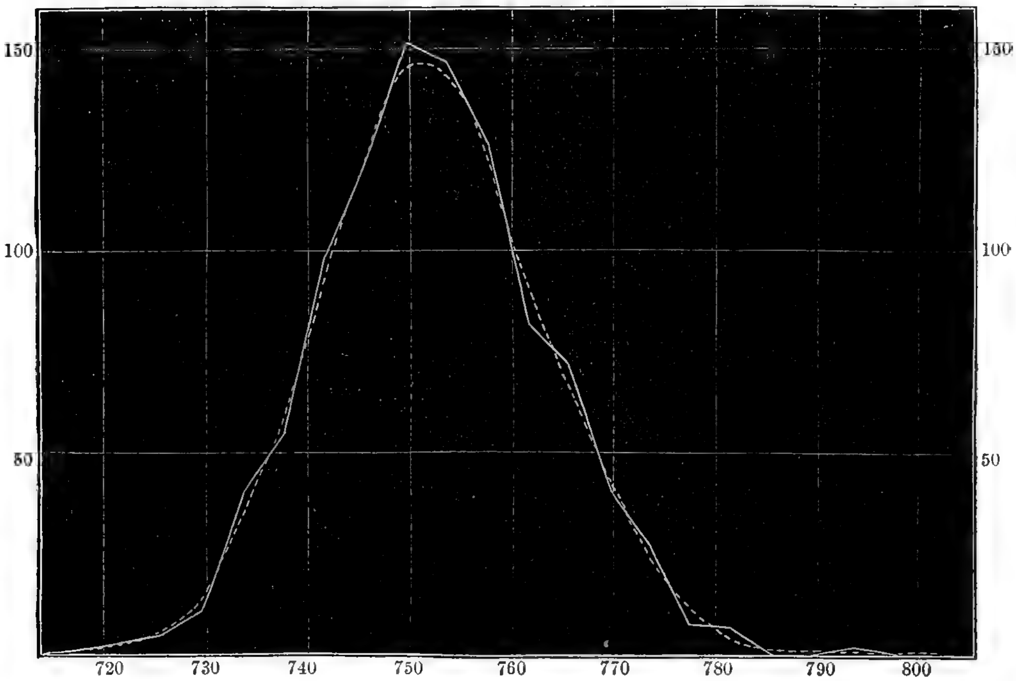

Diagram showing the magnitude of the antero-lateral margin (in terms of carapace-length) in 999 female shore-crabs from Naples.

Now suppose it became advantageous to the crabs, from some change in themselves or in their surroundings, that this part of their carapace should be as long as possible. Suppose the crabs in which it was shorter had a smaller chance of living, and of reproducing, than the crabs in which it was longer.

Suppose that crabs in which this dimension is longest were as much more productive than those in which it was shortest, as the most prolific marriages are more fertile than the least prolific marriages among ourselves. Professor Pearson has pointed out that half the children born in England are the offspring of a quarter of the marriages. If we suppose the productiveness among crabs to vary as much as it does among ourselves, only that in crabs the productiveness is greater, the greater the length of this bit of the carapace, then half of the next generation of crabs will be produced by that quarter of the present generation in which the antero-lateral margin is longest. And as the offspring will inherit a large percentage of the parental character, the mean of the race may be sensibly raised in a single generation.

This view of the possible effect of selection seems to have escaped the notice of those who consider that favourable variations are of necessity rare, and likely to be swamped by intercrossing when they do occur. You see that in this case there are a few individuals considerably different from the mean in either direction, and a very large number which differ from the mean *a little* in either direction. If such deviation be associated with some advantage to the crabs, so that crabs which possess such abnormality are more fertile than those which do not, it is a certainty that the mean character of the next generation will change, if only a little, in the direction advantageous to the race; and the opportunity for selective modification of this kind to occur in either direction is very nearly the same.

FIG. 4.

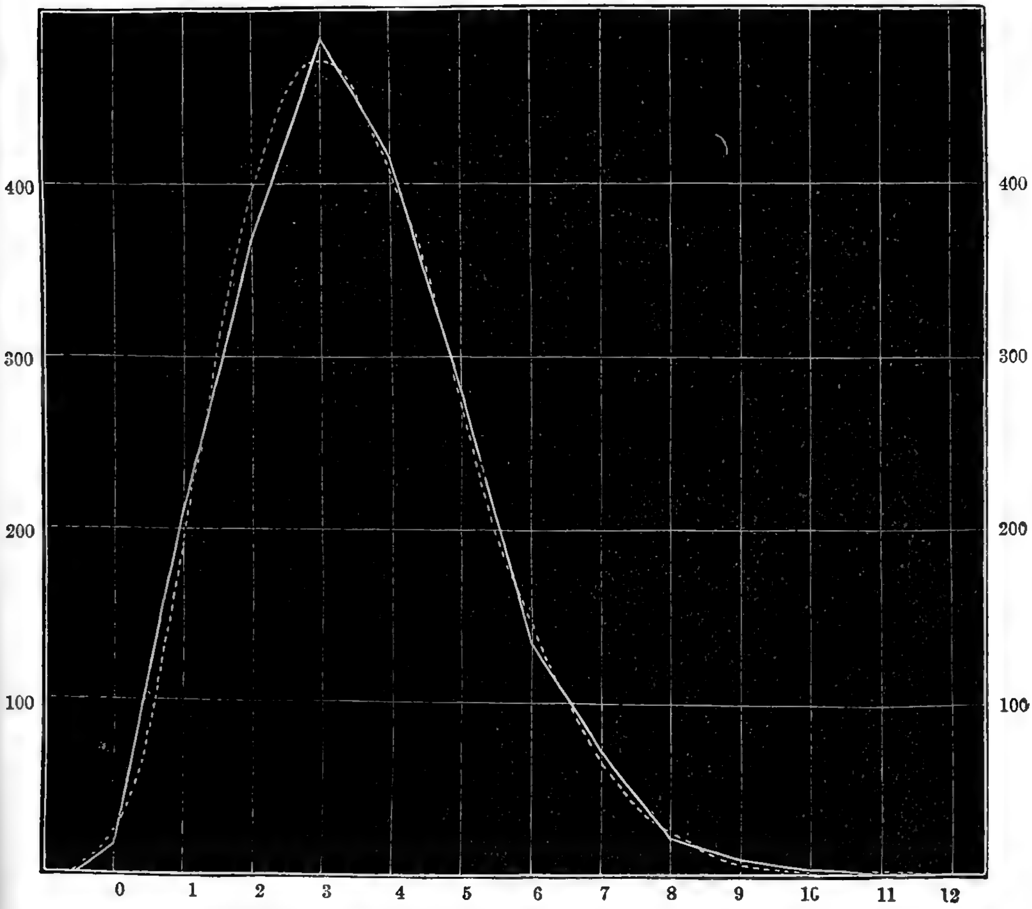

Diagram showing the number of Müller's glands in each of 2,000 female swine.

In the next case, this is not true.

The diagram (fig. 4) represents the number of female swine, out of a batch of two thousand examined in Chicago, which have a given number of Müllerian glands in the right fore-leg. The distribution is much more skew than in the case of the crabs, and you see again the very beautiful way in which Professor Pearson's curve expresses it. You see that the range of variation is much greater on one side of the mean than on the other; and the selective destruction necessary in order to raise the mean number of glands by one would be very different from the amount of destruction necessary in order to lower the mean by one. Further, the mean number of glands in these pigs is 3⅓; the number which occurs oftenest, the 'modal' number as Professor Pearson calls it,[1] is three. Now it is impossible to lower this number till it is less than 0, so that it can only be diminished by three; but it is conceivable that it should be increased by more than three. So that the amount of selective destruction required in order to change either the mean or the modal character of these pigs in one direction would be greater than the amount required in order to produce a change of equal magnitude in the opposite direction, and the amount of possible change is greater in one direction than in the other.

Now let us pass on to another example.

Table III. shows the variation in the number of petals in a race of buttercups studied by Professor de Vries. You see that the most frequent number of petals is five, and that no buttercups whatever have less than five petals, though a considerable number have more than five; and here again you see the way in which Professor Pearson's formula fits the observations.

TABLE III.—*Professor Pearson's expression for the variation in the race of Buttercups described by Professor de Vries.*

No. of Petals	5	6	7	8	9	10	11
Observed Frequency . .	133	55	23	7	2	2	0
Pearson's Theory . . .	136·9	48·5	22·6	9·6	3·4	0·8	0·2

You see that if this table (which is based on very few specimens) really represents the law of variability in these buttercups, no amount of natural or other selection can produce a race with less than five petals out of them. While it is conceivable that selection might quickly raise the normal number of petals, it could not diminish it, unless the variability of the race should first change.[2]

These examples, which are typical of others, must suffice to show the way in which the theory of Chance, as developed by Professor Pearson, can express the facts of organic variation.

I think you will agree that they also show the importance of investigating these facts. For of the four characters we have examined, we have seen that two—namely, human stature and the antero-lateral carapace-length of *Carcinus mœnas*—vary so as to afford nearly equal material for selective modification in either direction; one character, the number of Müller's glands in swine, offers distinctly greater facility for selective modification in one direction than in the opposite direction; and the last character, the number of petals in a race of buttercups, appears to offer scope for modification in one direction only, at least by selection in one generation.

Knowledge of this kind is of fundamental importance to the theory of Natural Selection. You have seen that the new method given to us by Professor Pearson affords a means of expressing such knowledge in a simple and intelligible form; and I, at least, feel very strongly that it is the duty of students of animal evolution to use the new and powerful engine which Professor Pearson has provided, and to accumulate this kind of knowledge in a large number of cases.

I know that there are people who regard the mode of treatment which I have tried to describe as merely a way of saying, with a pompous parade of arithmetic, something one knew before. This criticism of Professor Pearson's work was actually made to me the other day by an eminent biologist, whose name I will not

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[1] All attempts to confine the word 'average' to the most frequently occurring magnitude, and the word 'mean' to the arithmetic mean of the series, have failed to secure support. Therefore Professor Pearson's proposal to call the value which occurs oftenest the 'mode' is very useful.

[2] Of course we know that selection does change the variability of a race.

repeat. If there be any here who hold such an opinion, I would ask them to read Mr. Francis Galton's Essays on Heredity; where a simple and quite unexpected relation between parents and offspring is shown to be a direct consequence of the fact that they vary by chance. This is the first and the most striking deduction from the mathematical theory of organic variation, but it is not the only one. It is enough, however, to show that the new method is not only a simple means of describing the facts of variation, which facts very few people knew before, but it is a powerful instrument of research, which ought to be quickly and generally adopted by those who care for the problems of animal evolution.

I think I have said enough to convince you how entirely Professor Pearson's method promises to confirm the assertion that organic variation obeys the law of chance.

The other objections to Darwin's theory are not so easily answered. It is said that small variations cannot be supposed to affect an animal's chance of life or death; but few persons have taken any pains to find out in any given case whether the death-rate is in fact affected by small variations or not. It is said that the process of Natural Selection is so slow that the age of the earth does not give time for it to operate, but I know of few cases in which any attempt has been made to find out by actual observation how fast a species is really changing.

I can only attempt to discuss the importance of small variations, and the rate of organic change, in the one case which I happen to know. The particular case I have myself studied is the variation in the frontal breadth of *Carcinus mænas*.[1]

During the last six years my friend, Mr. Herbert Thompson, and I have studied in some detail the state of this character in the small shore-crabs which swarm on the beach below the laboratory of the Marine Biological Association at Plymouth.

I will show you that in those crabs small changes in the size of the frontal breadth do, under certain circumstances, affect the death-rate, and that the mean frontal breadth among this race of crabs is, in fact, changing at a rate sufficiently rapid for all the requirements of a theory of evolution.

In Table IV. you see three determinations of the mean frontal breadth of these crabs, expressed in terms of the carapace-length taken as 1000. You see that the mean breadth varies very rapidly with the length of the crab, so that it was necessary to determine it separately in small groups of crabs, such that the length of no two crabs in a group differed by more than a fifth of a millimetre. The first column of the table shows you the mean frontal breadth of twenty-five such groups, between 10 and 15 millimetres long, collected in 1893. These crabs were measured by Mr. Thompson. The second column shows you the mean frontal breadth in twenty-five similar groups of crabs, collected in 1895, and also measured by Mr. Thompson. You see that in every case the mean breadth in a group of crabs collected in 1895 is less than it was in crabs of the same size collected in 1893. The third column contains the result, so far as it is yet obtained, of my own measurement of crabs collected this year. It is very incomplete, because the 1895 crabs were collected in August and September, and I was anxious to compare them with crabs collected this year at the same season, so that there has not yet been time to measure the whole series. The measurements are sufficient, however, to show that the same kind of change has taken place during the last three years as that observed by Mr. Thompson in the interval between 1893 and 1895. Making every allowance for the smallness of the numbers so far measured this year, there is no doubt whatever that the mean frontal breadth of crabs from this piece of shore is considerably less now than it was in 1895 among crabs of the same size.[2]

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[1] In 1894 I gave an account of the variation of this dimension in female specimens of various sizes (*Roy. Soc. Proc.*, vol. lvii.), and I put forward an hypothesis of the amount of selective destruction due to variation in this character. That hypothesis neglected several important facts which I now know, and was open to other objections. I desire to replace it by the results of the observations here recorded.

[2] I shall of course consider it my duty to justify this statement by more extensive measurement as soon as possible. In the meantime, I may say that I have measured other small groups of crabs, male and female, from the same place, at different seasons of the years 1896–1898, and the results agree with those recorded in the table.

TABLE IV.—*The Mean Frontal Breadth Ratio of Male* Carcinus mœnas *from a particular patch of beach in Plymouth, in the years* 1893, 1895, *and* 1898.

Length of Carapace	Mean Frontal Breadth in terms of Carapace-length = 1000			
	1893 (Thompson)	1895 (Thompson)	1898 (Weldon)	No. of Crabs in the 1898 Group
10·1	816·17	809·08	—	—
10·3	812·06	804·82	—	—
10·5	807·37	803·27	—	—
10·7	808·96	801·69	—	—
10·9	805·07	799·27	—	—
11·1	802·50	794·12	784·25	4
11·3	798·18	792·38	787·36	11
11·5	797·19	788·83	784·00	9
11·7	794·28	785·29	782·44	16
11·9	791·45	786·53	780·09	11
12·1	788·38	780·61	775·25	16
12·3	783·98	779·50	773·42	12
12·5	783·99	776·50	767·00	11
12·7	783·58	773·43	772·43	14
12·9	777·38	773·63	764·67	15
13·1	776·63	771·61	760·13	16
13·3	774·60	766·21	761·29	7
13·5	766·91	763·96	759·56	16
13·7	767·63	762·00	757·00	16
13·9	763·73	759·40	756·10	10
14·1	758·94	757·00	742·00	13
14·3	756·90	755·77	747·86	7
14·5	762·60	754·45	744·44	9
14·7	753·00	749·84	739·22	8
14·9	751·32	748·03	742·83	6

These results all relate to *male* crabs. The change in female crabs during this time has been less than the change in male crabs, but it is, so far as my measurements at present permit me to speak, going on in the same direction as the change in male crabs.

I think there can be no doubt, therefore, that the frontal breadth of these crabs is diminishing year by year at a rate which is very rapid, compared with the rate at which animal evolution is commonly supposed to progress.

I will ask your patience for a little while longer, that I may tell you why I feel confident that this change is due to a selective destruction, caused by certain rapidly changing conditions of Plymouth Sound.

If you look at the chart, you will see that Plymouth Sound is largely blocked up, and its communication with the sea is narrowed by a huge artificial breakwater, about a mile long, so that the tidal currents enter it and leave it only by two openings. This huge modern barrier has largely changed the physical conditions of the Sound.

On either side of Plymouth itself a considerable estuary opens into the Sound, and each of these estuaries brings down water from the high granite moorlands, where there are rich deposits of china clay. Those of you who know Dartmoor will remember that in rainy weather a great deal of china clay is washed into the brooks and rivers, so that the water frequently looks white and opaque, like milk. Much of this finely divided china clay is carried down to the sea; and one effect of the breakwater has been to increase the quantity of this fine silt which settles in the Sound itself, instead of being swept out by the scour of the tide and the waves of severe storms.

So that the quantity of fine mud on the shores and on the bottom of the Sound is greater than it used to be, and is constantly increasing.

But this is not all. During the forty or fifty years which have gone by since the breakwater was completed, the towns on the shores have largely increased their population; the great dockyard at Devonport has increased in size and in activity; and the ships which visit the Sound are larger and more numerous than they were. Now the sewage and other refuse from these great and growing towns and dockyards, and from all these ships, is thrown into the Sound; so that while it is more difficult than it used to be for fine silt to be washed out of the Sound, the quantity thrown into it is much greater than it was, and is becoming greater every day.

It is well known that these changes in the physical conditions of the Sound have been accompanied by the disappearance of animals which used to live in it, but which are now found only outside the area affected by the breakwater.

These considerations induced me to try the experiment of keeping crabs in water containing fine mud in suspension, in order to see whether a selective destruction occurred under these circumstances or not. For this purpose, crabs were collected and placed in a large vessel of sea-water, in which a considerable quantity of very fine china clay was suspended. The clay was prevented from settling by a slowly moving automatic agitator; and the crabs were kept under these conditions for various periods of time. At the end of each experiment the dead were separated from the living, and both were measured.

FIG. 5.

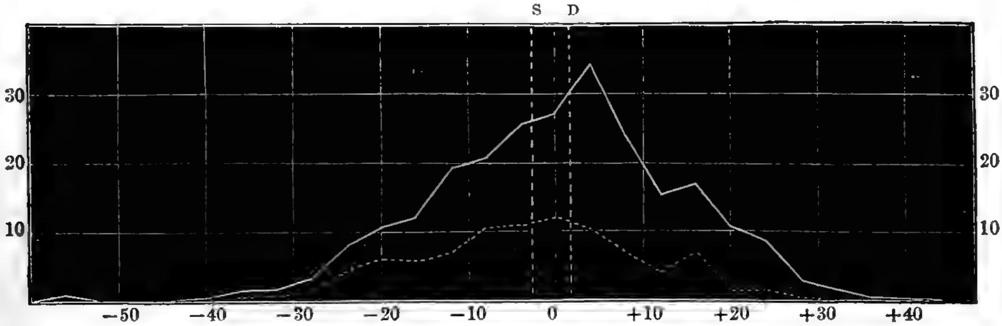

Diagram showing the effect of china clay upon 248 male crabs. The upper curve shows the distribution of frontal breadths in all these crabs; the dotted curve the distribution of frontal breadths in the survivors. The dotted line S shows the mean of the survivors; the line D the mean of the dead.

In every case in which this experiment was performed with china clay as fine as that brought down by the rivers, or nearly so, the crabs which died were on the whole distinctly broader than the crabs which lived through the experiment, so that a crab's chance of survival could be measured by its frontal breadth.

When the experiment was performed with coarser clay than this, the death-rate was smaller, and was not selective.

I will rapidly show you the results of one or two experiments. The diagram (fig. 5) shows the distribution of frontal breadths, about the average proper to their length, in 248 male crabs treated in one experiment. Of these crabs, 154 died during the experiment, and 94 survived. The distribution of frontal breadths in the survivors is shown by the lower curve in the diagram, and you see that the mean of the survivors is clearly below the mean of the original series, the mean of the dead being above the original mean.

Two other cases, which are only examples of a series in my possession, show precisely the same thing.[1]

These experiments seemed to me to show that very finely divided china clay

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[1] It is impossible in this place to give a full account of the experiments referred to, and a multiplication of mere small-scale diagrams seems useless, so that only one of those exhibited when the address was delivered is here reproduced.

does kill crabs in such a way that those in which the frontal breadth is greatest die first, those in which it is less live longer. The destruction is selective, and tends to lower the mean frontal breadth of the crabs subjected to its action. It seemed to me that the finer the particles used in the experiments, that is to say, the more nearly they approached the fineness of the actual silt on the beach, the more selective their action was.

I therefore went down to the beach, where the crabs live, and looked at the silt there. This beach is made of moderately small pieces of mountain limestone, which are angular and little worn by water. The pieces of limestone are covered at low tide with a thin layer of very fine mud, which is much finer than the china clay I had used in my experiments, and remains suspended in still water for some time. Under these stones the crabs live, and the least disturbance of these stones raises a cloud of very fine mud in the pools of water under them. By washing the stones of the beach in a bucket of sea water, I collected a quantity of this very fine mud, and used it in a fresh series of experiments, precisely as I had before used china clay, and I obtained the same result. The mean frontal breadth of the survivors was always smaller than the mean frontal breadth of the dead.

I think, therefore, that Mr. Thompson's work, and my own, have demonstrated two facts about these crabs; the first is that their mean frontal breadth is diminishing year by year at a measurable rate, which is more rapid in males than in females; the second is that this diminution in the frontal breadth occurs in the presence of a material, namely, fine mud, which is increasing in amount, and which can be shown experimentally to destroy broad-fronted crabs at a greater rate than crabs with narrower frontal margins.

I see no shadow of reason for refusing to believe that the action of mud upon the beach is the same as that in an experimental aquarium; and if we believe this, I see no escape from the conclusion that we have here a case of Natural Selection acting with great rapidity because of the rapidity with which the conditions of life are changing.

Now, if we suppose that mud on the beach has the same effect upon crabs as mud in an aquarium has, we must suppose that every time this mud is stirred up by the water a selective destruction of crabs occurs, the broad-fronted crabs being killed in greater proportion than the narrow-fronted crabs.

Therefore, if we could take a number of young crabs, and protect them through a certain period of their growth from the action of this selective mud, the broad-fronted crabs ought to have as good a chance of life as the rest; and in consequence the protected crabs should contain a larger percentage of broad individuals than wild crabs of the same age; and the mean frontal breadth of such a protected population ought to be greater, after a little time, than the mean frontal breadth of wild crabs, in which the broad individuals are being constantly destroyed.

It is difficult to perform this experiment, because one cannot know the age of a crab caught on the shore. But so far as one can judge the age of a crab by its length, I can show you that the thing which ought to happen, on the hypothesis that such selective destruction is going on, does actually happen.

I established an apparatus consisting of some hundreds of numbered glass bottles, each bottle being provided with a constant supply of clean sea-water by means of a system of glass syphons. Into each of these bottles I placed a crab from the beach. After a considerable number of deaths had occurred, a series of crabs was finally established, each crab living in a numbered bottle, until it had cast its shell. The process of moulting involves no distortion of the carapace, which could affect the measurements concerned, and therefore each cast shell was carefully measured. The measurements of these shells were carefully compared with measurements of wild crabs of the same size, and the mean frontal breadth of these shells was a little *less* than the mean breadth in wild crabs of corresponding length.[1]

After each crab had moulted, it was left in its bottle until it had grown and

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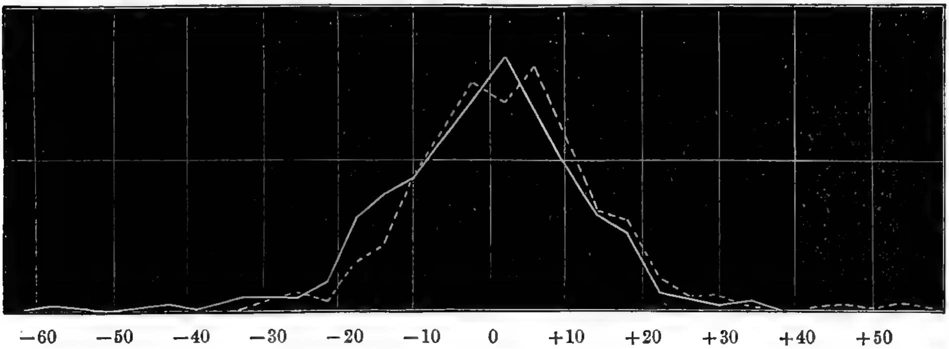
[1] This was probably due to the death-rate during acclimatisation being selective. It was very difficult to keep the apparatus clean; and the deaths which occurred

had hardened a new shell. It was then killed and measured, and the measurements obtained were compared with measurements of wild crabs of corresponding size. This time the captive crabs were unmistakably *broader* than wild crabs of their own size, and there were a few of the protected crabs which were very remarkably broad. The distribution of abnormalities before and after moulting is shown in fig. 6.

FIG. 6.



Distribution of abnormality of frontal breadth ratios in 527 female crabs before and after moulting in captivity. The continuous line shows the distribution before, the dotted line after moulting.

This is precisely the result which we ought to have obtained if the hypothesis suggested by the study of mud were true. By protecting crabs through a period of their growth, we ought to raise the mean frontal breadth, and to obtain a greater percentage of abnormally broad crabs, and that is what we have seen to occur.

Of course, this experiment by itself is open to many objections. The estimate of age by size is a dangerous proceeding, and it is difficult to exclude the possibility that confinement in a bottle may directly modify a crab during the critical period of moulting, and so on. All these points would have to be discussed at greater length than your patience would bear, before we could accept this experiment by itself as a proof that some selective agent exists on the shore which is absent from the bottles. At the same time, the result of this experiment is exactly what we should expect to find if such a selective agent did exist, and so it is in complete harmony with the evidence already put before you.

Of course, if the observed change in frontal breadths is really the result of selection, we ought to try to show the process by which this selection is effected.

This process seems to be largely associated with the way in which crabs filter the water entering their gill-chambers. The gills of a crab which has died during an experiment with china clay are covered with fine white mud, which is not found in the gills of the survivors. In at least ninety per cent. of the cases this difference is very striking; and the same difference is found between the dead and the survivors in experiments with mud.

I think it can be shown that a narrow frontal breadth renders one part of the process of filtration of water more efficient than it is in crabs of greater frontal breadth.

It would take too long to go into that matter now, and I shall not attempt to do so. I will only now ask you to consider one or two conclusions which seem to me to follow from what I have said.

were in most cases due to the presence of putrescent bits of food, which had not been removed.

A subsequent experiment was made with the same apparatus, in which crabs were kept in putrid water until a large percentage had died; and the mean frontal breadth of the survivors was found to be distinctly less than the mean frontal breadth of the dead.

I hope I have convinced you that the law of chance enables one to express easily and simply the frequency of variations among animals; and I hope I have convinced you that the action of Natural Selection upon such fortuitous variations can be experimentally measured, at least in the only case in which anyone has attempted to measure it. I hope I have convinced you that the process of evolution is sometimes so rapid that it can be observed in the space of a very few years.

I would urge upon you in conclusion the necessity of extending as widely as possible this kind of numerical study. The whole difficulty of the theory of Natural Selection is a quantitative difficulty. It is the difficulty of believing that in any given case a small deviation from the mean character will be sufficiently useful or sufficiently harmful to matter. That is a difficulty which can only be got rid of by determining in a number of cases how much a given variation does matter; and I hope I have shown you that such determination is possible, and, if it be possible, it is our duty to make it.

We ought to know numerically, in a large number of cases, how much variation is occurring now in animals; we ought to know numerically how much effect that variation has upon the death-rate; and we ought to know numerically how much of such variation is inherited from generation to generation. The labours of Mr. Galton and of Professor Pearson have given us the means of obtaining this knowledge, and I would urge upon you the necessity of obtaining it. For numerical knowledge of this kind is the only ultimate test of the theory of Natural Selection, or of any other theory of any natural process whatever.

The Biological Exhibition at the Zoological Gardens was opened by the Right Hon. Sir John Lubbock, M.P., D.C.L., F.R.S.

FRIDAY, SEPTEMBER 9.

The following Papers and Reports were read:—

1. *The Proof obtained by Guy A. K. Marshall that* Precis octavia-natacensis *and* P. sesamus *are seasonal forms of the same species. By* Professor E. B. Poulton, *M.A., F.R.S.*

2. *Photographic Records of Pedigree Stock.*
By Francis Galton, *M.A., F.R.S.*—See Reports, p. 597.

3. *Preliminary Note on the Races and Migrations of the Mackerel (Scomber scomber). By* Walter Garstang, *M.A., Naturalist in charge of Fishery Investigations under the Marine Biological Association; late Fellow of Lincoln College, Oxford.*

The present note contains the principal results of an attempt to determine whether there are any racial peculiarities in groups of mackerel taken in different localities. Such peculiarities have not hitherto been recognised, even as between American and British representatives of the species; but it is clear that the establishment of such peculiarities would affect to a considerable degree our ideas concerning the migrations of this fish.

During the past year I have determined the peculiarities of more than 1,600 mackerel in regard to 10 chosen characters. Of these fish, 100 were obtained at Newport, R.I., U.S.A., and were forwarded to me through the friendly agency of the U.S. Commission of Fish and Fisheries. The remainder, 1,529 in all, have been taken at various points round the British Isles—400 in the North Sea (off Lowestoft and Ramsgate), 300 near Plymouth, 74 off the Scilly Isles, 100 near Brest, and 655 off the S.W. coast of Ireland (Kinsale and co. Kerry). The Irish fish are further divisible into 310 autumn fish and 345 spring fish.

The chief characters chosen for examination were:—

A.—The number of black transverse bars or stripes on one side (the left) of the fish.

B.—The number of transverse bars on one side (the left) which cross or meet the lateral line.

C.—The presence or absence of round black spots ('intermediate spots') between the bars of series A. The variation of this character is tabulated under two heads:—(1) The number of fish per centum which possess one or more of these intermediate spots, and (2) the total number of such spots per hundred fish (the left side only of each fish being considered).

D.—The number of rays in the first dorsal fin.

E.—The number of rays in the second dorsal fin, including any incipient finlets which are still partially connected with the fin by a low web or ridge, or which are merely closely approximated to the fin and erectile with it.

F.—The number of dorsal finlets, including all incipient finlets described under E.

The accompanying table shows the results of this examination. The mean values of each character for the total number of fish from each locality are expressed in terms of the general mean, as + or − deviations from the value of that mean. The general mean value of each character is the arithmetic mean of all the observed values of that character, the American data alone excepted. The American mean values for several of the characters, especially A, B, C, and F, differ to such an extent from the British means, that there can be no further doubt as to the existence of racial peculiarities which distinguish American from British specimens of the mackerel. As compared with the British mackerel, the American fish possesses the following racial characteristics—(1) A higher number of transverse bars, (2) much greater spottiness, (3) a smaller number of fin-rays in the second dorsal fin, and (4) a greater number of dorsal finlets. These characteristics, it must be borne in mind, are *average* distinctions, and do not suffice to distinguish every individual. But, I may add, they are so marked in the present case, that on examining a sample of a dozen fish at Toronto during the last meeting of this Association, I became there and then convinced of the existence of racial peculiarities in this species.

With regard to the British fish, the range of variation is very limited, especially in the case of the second dorsal fin, the greatest deviation from the general mean value of which does not amount to $\frac{1}{10}$ of a fin-ray in any sample of 100 fish. The total number of fish from the various localities is seen to be insufficient in this case to afford a basis for the establishment of racial differences. In the case of the first dorsal fin the variation is greater, but here the difficulty of accurately determining in all instances the exact number of fin-rays present (owing to the extreme minuteness of the posterior rays) has also provided an obstacle to very definite results. Nevertheless the characters A, B, C, and F, the variation of which has been seen to be so marked in the American fish, also provide sufficient data for separating the British fish into at least two groups of different racial tendency. These groups are—(1) fish from the North Sea and English Channel, and (2) Irish fish, both autumn and spring forms. The table shows that fish from the North Sea and Plymouth agree in the following points—(1) the mean number of transverse bars A and B is below the general average, and (2) the mean number of spotty fish and of intermediate spots is above the general average. Moreover, the mean number of dorsal finlets was below the average in the case of 300 fish from Lowestoft and 300 from Plymouth, although remarkably above the average in the case of 100 fish from Ramsgate.

On the other hand, the autumn and spring forms of Irish fish agree in the possession of characteristics which are just the reverse of those which distinguish the North Sea and Channel fish.

It would appear from these results that we have two races of mackerel on the English coasts—an Irish or Atlantic race, and a race which frequents the English Channel and the North Sea.

The fish taken off Scilly and Brest offer characteristics which are in several respects intermediate between the two principal races here distinguished, but the numbers examined up to the present time are not sufficient to enable me to decide upon their relationships in a definite manner.

If these results be accepted or confirmed, the problems of the migrations of the mackerel and of its winter home are considerably simplified. The Irish fish in winter must remain off their own coasts, or they would lose their peculiarities by mixture with other races. The North Sea and Channel fish probably have the same winter haunts off the mouth of the English Channel—not too far to the westward, or they would mix with the Irish fish. That the North Sea fish migrate into the Channel in winter is rendered probable by the enormous concentration of mackerel in the southern part of the North Sea in autumn, and by the prolongation of the mackerel fishery far into the winter off the Devon and Cornish coasts of the Channel, long after the fish have disappeared from the North Sea and the Irish coasts alike.

A complete account of this investigation, with tables showing the variation of each character, will appear in the forthcoming number of the 'Journal of the Marine Biological Association.'

Summary showing Deviations from the General Mean in respect of all Characters.

—	No. of Fish	Bars A	Bars B	C		D.—1st Dorsal Fin	E.—2nd Dorsal Fin	F.—Dorsal Finlets
				Spotty Fish %	No. of Spots %			
General Mean . .	—	26·967	18·370	19	31	12·086	11·940	5·024
Lowestoft . . .	300	−0·22	−0·14	−1	− 4	+0·03	+0·003	−0·004
Ramsgate . . .	100	−0·05	+0·06	+9	+26	−0·05	+0·030	+0·026
Plymouth . . .	300	−0·17	−0·16	+2	+10	+0·09	±0·000	−0·007
Scilly	74	−0·15	+0·26	−1	+ 1	+0·41	+0·073	−0·010
Brest	100	−0·12	+0·28	+7	+ 1	−0·09	−0·040	−0·014
Kinsale	410	+0·18	+0·09	±0*	− 2*	−0·15	−0·013	+0·005
Co. Kerry . . ,	245	+0·30	±0·00	−9	−16	+0·02	+0·003	+0·004
North Sea . . .	400	−0·19	−0·09	+2	+ 3	+0·01	+0·010	+0·003
Plymouth . . .	300	−0·17	−0·16	+2	+10	+0·09	±0·000	−0·007
Scilly and Brest .	174	−0·13	+0·27	+3	+ 1	+0·13	+0·008	−0·012
Irish, Autumn .	310	+0·26	+0·10	+1*	− 1*	−0·21	+0·008	+0·011
,, Spring . . .	345	+0·20	+0·01	−7	−12	+0·04	−0·021	−0·001
North Sea and Channel . . .	700	−0·18	−0·12	+2	+ 6	+0·045	+0·006	−0·001
Scilly and Brest .	174	−0·13	+0·27	+3	+ 1	+0·13	+0·008	−0·012
Irish Fish . . .	655	+0·23	+0·05	−4*	− 8*	−0·081	−0·007	+0·005
Newport, U.S.A. .	100	+0·41	+0·51	+47	+184	−0·066	−0·090	+0·166

* These Means were derived from a total number of fish less by 99 than the number stated in the first column in each case.

4. *On a Proposed Biological and Physical Investigation of the English Channel. By* WALTER GARSTANG *and* H. N. DICKSON.

5. *On the Phylogeny of the Arthropod Amnion.*
By ARTHUR WILLEY, *D.Sc. Lond., Hon. M.A. Cantab.*

Until recently the formation of the amnion of the higher vertebrates was wont to be explained on mechanical grounds, the embryo sinking by its own weight into the yolk in the case of the Sauropsida and into the blastodermic vesicle in the case of the Mammalia. In 1894 Professor Hubrecht entered a welcome protest against the mechanical theory of the vertebrate amnion, replacing it by a remarkable theory as to the phyletic origin of the amnion.[1]

Owing to lack of data no analogous theory has hitherto been possible with regard to the amnion of insects. If it were found that a common principle governs the theories applied to the explanation of these similar but not homologous structures, the one theory would be an important complement of the other. The embryos of a new species of *Peripatus* which I found a year ago in New Britain, and have recently described,[2] seem to me to supply the material necessary for coping successfully with this problem.

These embryos, for a full account of which my memoir should be consulted, possess a large trophic organ, the ectoderm of which consists of glandular absorbent cells adapted for the intra-uterine nutrition of the embryo. This ectodermic layer may be called the trophoblast.

The theory, which I shall develop fully in a forthcoming paper,[3] seeks to prove that the glandular trophoblast arose in adaptation to a viviparous habit acquired by a terrestrial descendant of an aquatic ancestor, and that this became transformed into the non-glandular protective envelope, known as the serosa, in correlation with the secondary deposition of yolk-laden eggs.

As the amnion of the insect egg is subsidiary to the serosa, and the latter, being a direct derivative of the blastoderm, is the older structure, the theory which will adequately account for the serosa will, in its general terms, account equally for the amnion.

6. *On the Micro-chemistry of Cells. By* Professor A. B. MACALLUM.

7. *A Case of Protective Resemblance in Mice. By* Dr. H. L. JAMESON.

8. *Final Report on the Life Conditions of the Oyster, Normal and Abnormal.*—See Reports, p. 559.

9. *Interim Report on Zoological Bibliography and Publication.* See Reports, p. 558.

10. *Remarks on the Report of the International Zoological Congress on Nomenclature. By* Rev. T. R. R. STEBBING, F.R.S.

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[1] A. A. W. Hubrecht, 'Die Phylogenese des Amnions und die Bedeutung des Trophoblastes,' *Verh. Kon. Akad. van Wetenschappen*, Amsterdam, 1894.

[2] A. Willey, 'The Anatomy and Development of *Peripatus novæ-britanniæ*,' in *Zoological Results*, &c., Cambridge University Press, 1898.

[3] To be published in the *Quart. Journ. of Microscopical Science.*

11. *Report on the Index Animalium.*—See Reports, p. 570.

12. *Report on the Canadian Biological Station.*—See Reports, p. 582.

13. *Report on the Investigations made at the Marine Biological Laboratory, Plymouth.*—See Reports, p. 583.

14. *Report on the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 587.

15. *Interim Report on Bird Migration in Great Britain and Ireland.* See Reports, p. 569.

16. *Report on the Zoology of the Sandwich Islands.*—See Reports, p. 558.

SATURDAY, SEPTEMBER 10.

The Section did not meet.

MONDAY, SEPTEMBER 12.

The following Papers were read:—

1. *An Experimental Inquiry into the Struggle for Existence in Certain Common Insects. By* EDWARD B. POULTON, *M.A., F.R.S., Hope Professor of Zoology, Oxford, and* CORA B. SANDERS.

Many Lepidoptera have been proved to possess the power of adjusting the larval or pupal colours to those of the immediate surroundings. This power can only be exercised once in the case of the pupa (viz. at the end of larval life), and rarely, if ever, more than once or twice in the case of the larva. Many naturalists consider that the power is protective, and has been produced by the operation of natural selection. Others have doubted this conclusion, and W. Bateson[1] has attempted to cut away the foundation of such an interpretation as regards the pupa of *Vanessa urticæ* by arguing that there is no struggle for existence during this brief stage. This argument was opposed, and the lines of an experimental inquiry were suggested in the same year by one of us.[2] In the discussion which followed a paper on mimicry, read before the Linnean Society on March 17, 1898,[3] it was strongly urged, especially by Professor Weldon, that such an experimental inquiry should be conducted. Our present work is the outcome of that discussion, and we desire to express our thanks to the Government Grant Committee of the Royal Society for assistance in carrying on the investigation.

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[1] *Trans. Ent. Soc.* Lond. 1892, pp. 212, 213.

[2] Poulton, *Trans. Ent. Soc.* Lond. 1892, pp. 471–477.

[3] Poulton, *Natural Selection the Cause of Mimetic Resemblance and Common Warning Colours.* Not yet published.

We determined to concentrate our attention on the pupæ of certain butterflies, this stage being especially suitable because the chrysalis is motionless, and, therefore, remains in any position in which it has been fixed until it is seized by an enemy or emerges as an imago. Our object was to decide:—(1) whether there is a struggle for existence during the pupal stage; (2) whether the struggle, if it takes place, is decided by the conspicuousness of the pupa.

The inquiry was almost confined to the pupa of *Vanessa urticæ*, which ranges from a brilliant golden appearance through increasingly dark varieties up to black. Seven degrees of colour variation were distinguished, as in the researches into the sensitiveness of this pupa to its environment.[1] Captured larvæ were placed in boxes lined with gilt, black, and yellow paper, &c., so as to produce pupæ with different degrees of colour, the aim being to obtain the most contrasted results. The pupæ were then fixed to the surfaces upon which they are known to occur in Nature, and others upon which they may be supposed to occur—viz. the food plant (nettle), tree trunks, fences, stone walls, and rocks—while a few were placed on the ground. They were attached by small nails driven through the silken web, in which the caudal hooks were entangled, or (in the case of the food plant) by sewing the web on to the leaves or stem with green silk; in other cases the hooks were entangled in the outer part of a little plug of cotton wool, which was forced into a crack in bark, wood, or stone. Careful notes were taken of the degree of colour, method, and height of attachment, character of surface, and the date of all visits until the pupa either disappeared, emerged, or died. With very few exceptions, visits were made every twenty-four hours, and in many cases at much shorter intervals. Over 600 pupæ of this species were thus fixed, and of these about 550 disappeared or emerged. The experiments were conducted in three different localities—Oxford, Switzerland, and the Isle of Wight—with very divergent results, as will be seen from the following table:—

Surfaces to which Pupæ were fixed	Oxford		Mürren		Visp		Isle of Wight: St. Helen's	
	June 25–July 23		July 11–July 17		July 21–July 25		Aug. 2–Sept. 3	
	Taken	Emerged	Taken	Left	Taken	Left	Taken	Emerged
Bark	29	0	—	—	5	16	135	84
Fences	4	0	0	18	—	—	90	8
Rock	—	—	4	31	7	25	—	—
Walls	4	0	—	—	1	5	14	12
Nettle	7	4	—	—	—	—	20	15
Ground . . .	11	0	—	—	—	—	—	—
Totals . . .	55	4	4	49	13	36	259	119

It should be noted that the Swiss pupæ which were not taken are marked 'left' because many of them did not emerge, but were removed at the close of the visit and used over again. The results thus tabulated leave no doubt about the existence of an immense amount of extermination at Oxford, and, although much less, a large amount in the Isle of Wight, while there was comparative immunity in the two Swiss localities. This strong contrast is probably to be explained by the scarcity of small birds in the latter, and their abundance in England, and especially in Oxford, together with the fact that the Oxford experiments were conducted earlier in the year. Other considerations point to the same conclusion—viz. that birds are the enemies in question; the inaccessible position of the pupæ, which were nearly always fixed at a height of about four feet from the ground; the fact that the hard caudal extremity was frequently left attached after the pupa

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[1] Poulton, *Phil. Trans. Roy. Soc.*, vol. clxxviii. (1887), B. p. 320; and *Trans. Ent. Soc.* Lond. 1892, p. 362.

itself had been taken; the excessive variation in mortality in neighbouring localities, corresponding to well-known facts in the distribution of birds. A watch was kept in localities where the pupæ were known to disappear rapidly, and, in a single instance, a great tit was seen to creep over the bark of a tree, from which the pupa was then found to have gone.

So far as the observations extended, we inferred that the comparative freedom of the Swiss pupæ from the attacks of Vertebrate enemies is compensated by the far greater destruction of the larvæ by insect parasites. It is probable that the birds which attack the English pupæ benefit the larvæ by keeping down the number of parasites.

In the course of the inquiry the possibility was suggested that perhaps the birds actually see the pupæ being suspended, and afterwards search the spot. A large number of pupæ were, therefore, fixed at night by the light of a lantern, but, so far as we can judge from general impressions (the analysis of the results being unfinished), no difference was caused. It was also thought that, when several pupæ were suspended in close proximity, the birds, after finding one or more, might search the neighbourhood with especial keenness, so that the chances of successful concealment would be smaller than those of isolated pupæ. In order to test this suggestion, a number of pupæ were scattered over a large area, successive individuals being separated by a distance of about 100 yards or more. Here, too, our present impression is that little, if any, difference was produced. Both these modifications of the usual conditions of experiment were made in the Isle of Wight.

The question whether there is a struggle for existence during the pupal period of *Vanessa urticæ* is answered with certainty in the affirmative as regards those localities where small birds are abundant. In such places it is now proved that there is a tremendous struggle with an immense mortality, in spite of the brevity of the pupal stage (from ten days to three weeks in length).

The attempt was also made to answer the second question whether the struggle is decided by the conspicuousness of the pupa. First, as to conspicuousness in form, pupæ were fixed to surfaces which unequally concealed them; thus the rough surfaces of stone and bark (rough-barked trees being almost invariably selected), and the shelter afforded by overhanging leaves of nettle, concealed their rough angular forms far more than the comparatively smooth surface of fences. Looking at the table on page 907, it is seen that at Oxford butterflies only emerged from pupæ fixed to nettles, while in the Isle of Wight the mortality on fences (90 taken to 8 emerged), was enormously greater than on bark (135 to 84), walls (14 to 12), and nettle (20 to 15). When therefore the pupa is suspended from a surface against which it stands out conspicuously, it is in far greater danger than when it is fixed to one upon which it is concealed. This result is inexplicable, except on the theory that the sense of sight is important to enemies in the discovery of the pupæ.

Secondly, as to conspicuousness in colour. In Nature the golden forms of the pupa of this species are produced upon nettle, the darker forms on walls, rocks, fences, and probably bark; furthermore the darkest varieties are produced on the darkest surfaces. In fixing the pupæ, part were distributed as they are in Nature, while part were given a reverse arrangement—dark forms being fixed to nettle, and golden forms to black fences and dark surfaces of bark, &c. Some of the experiments gave extremely positive results, in that the mortality among the latter pupæ was far higher than among the former; other experiments were negative. Until the whole of the experiments have been analysed in far more detail than has as yet been possible, we cannot make any statement as to the general bearing of the inquiry upon the danger or otherwise of conspicuousness in colour, although the danger of conspicuousness of form has been shown to be conclusively proved.

It may be supposed that the experiments were vitiated by the accidental loss of the pupæ. Many considerations, however, indicate that no serious error has been introduced in this way. In the absence of enemies, in Switzerland, the pupæ remained suspended until they emerged or until we removed them, and this was also the case in the places of small mortality in the Isle of Wight; in many places the ground was bare, and a fallen pupa (always searched for) would have been easily seen; the hard caudal extremity was frequently left fixed to the supporting surface; the different results obtained on fences and on bark, &c., are manifestly inexplicable on this ground, the means of fixation being the same. The act of emergence was obviously a much severer test of our method of suspension than that supplied by the motionless pupa; and yet in a large proportion of cases the empty pupal shell was found hanging to the support, and thus remained for days, in spite of the fact that its lightness enabled each breath of wind to blow it about.

In future inquiries we trust that a pupa with a wider colour variation than *V. urticæ* may be available. All attempts to obtain the larva of *Vanessa io* were unsuccessful, but next year we hope to get it and test the bright green and dark forms which its pupa assumes. Other excellent examples would be the bright green, bone-coloured, and dark forms of the pupæ of *Pieris napi* and *P. rapæ*, which have the further advantage of being available for experiment during the winter. Through the kindness of Mr. F. Merrifield we shall be able to carry on the inquiry with these latter and some other species during the winter of 1898–9, when we hope again to appeal to the kindness of the President and Fellows of Magdalen College for the opportunity of continuing the investigation begun during the past summer in the College grounds.

We also desire to acknowledge the kind assistance we have received from Miss Drummond and Miss Sidgwick in taking notes of the Oxford pupæ during our absence in Switzerland, and from Miss Notley for much kind help in the Isle of Wight. Professor H. F. Osborn, Professor F. O. Bower, and Mr. Arthur J. Evans also witnessed the experiments in the Isle of Wight, and offered valuable suggestions and criticisms.

The investigation, of which this is a brief epitome, was manifestly a preliminary inquiry: it has nevertheless yielded far more definite results than we ventured to hope for when we undertook it.

2. *Animal Intelligence as an Experimental Study.*
By Professor C. Lloyd Morgan.

It was urged that intelligence in animals is an important factor in zoological evolution; that the day of collected anecdotes had passed; and that experimental work was much needed. Mr. Thorndike's recent experiments on cats were described, and both the apparatus employed and the curves expressing some of his results were illustrated on the screen. The experiments supported the contention that the method of animal intelligence was that of trial and error, the profiting by chance success. Mr. Thorndike's method was criticised in a friendly spirit; and recent observations on a fox terrier leading to similar conclusions were briefly described. It was urged that the experimental method gave better opportunities of exact record and a clearer insight into the nature of the association process involved than merely casual observation could possibly do.

3. *On the Families of Sauropodous Dinosauria.* *By* Professor O. C. Marsh.

The sub-class Dinosauria as known to-day the author divided into three orders: the *Theropoda*, or carnivorous forms; the *Sauropoda*, or herbivorous quadrupedal forms; and the *Predentata*, also herbivorous, and including several sub-orders—viz., the *Stegosauria* and *Ceratopsia*, both quadrupedal, and the *Ornithopoda*, containing bipedal bird-like reptiles.[1]

The principal characters of the order *Sauropoda* here discussed may be briefly stated as follows:—

[1] The Dinosaurs of North America, *Sixteenth Annual Report U.S. Geological Survey*. 84 plates. Washington, 1896.

Order SAUROPODA.

External nares at top of skull; premaxillary bones with teeth; crowns of teeth rugose and more or less spoon-shaped; large antorbital openings; no pineal foramen; alisphenoid bones; brain-case ossified; no collumellæ; postoccipital bones; no predentary bone; dentary without coronoid process. Cervical ribs co-ossified with vertebræ; anterior vertebræ opisthocœlian, with neural spines bifid; posterior trunk vertebræ united by diplosphenal articulation; presacral vertebræ hollow; each sacral vertebra supports its own sacral rib, or transverse process; no diapophyses on sacral vertebræ; neural canal much expanded in sacrum; first caudal vertebra bi-convex; anterior caudals procœlian. Sternal bones parial; sternal ribs ossified. Ilium expanded in front of acetabulum; pubes projecting in front and united distally by cartilage; no postpubis. Limb bones solid; fore and hind limbs nearly equal; metacarpals longer than metatarsals; femur longer than tibia; astragalus and calcaneum not fitted to end of tibia; feet plantigrade, ungulate; five digits in manus and pes; second row of carpal and tarsal bones unossified; locomotion quadrupedal.

(1) Family *Atlantosauridæ.* A pituitary canal; large fossa for nasal gland. Distal end of scapula not expanded; coracoid quadrilateral. Sacrum hollow; ischia directed downward, with expanded extremities meeting on median line. Anterior caudal vertebræ with lateral cavities; remaining caudals solid; chevrons single.

Genera *Atlantosaurus, Apatosaurus, Brontosaurus.* Include the largest known land animals. Jurassic, North America.

(2) Family *Diplodocidæ.* External nares at apex of skull; no depression for nasal gland; two antorbital openings; large pituitary fossa; dentition weak, and in front of jaws only; brain inclined backward; dentary bone narrow in front. Scapula with shaft somewhat enlarged at summit. Ischia with shaft expanded distally, directed downward and backward, with sides meeting on median lines. Sacrum hollow, with three co-ossified vertebræ. Anterior caudal vertebræ procœlian, with sides deeply excavated, and chevrons single; median caudals excavated below, with chevrons double, having both anterior and posterior branches; distal caudals elongate, with rod-like chevrons.

Genera *Diplodocus* and *Barosaurus.* Jurassic, North America.

(3) Family *Morosauridæ.* External nares anterior; large fossa for nasal gland; small pituitary fossa; dentary bone massive in front; teeth very large. Shaft of scapula expanded at distal end; coracoid suboval. Sacral vertebræ four in number, and nearly solid; ischia slender, with twisted shaft directed backward, and sides meeting on median line. Anterior caudals solid; chevrons single.

Genera *Morosaurus, Camarasaurus* (?) (Amphicœlias). Jurassic, North America and Europe.

(4) Family *Pleurocœlidæ.* Dentary bone constricted medially; teeth with crowns like those of *Diplodocus.* Cervical vertebræ elongate; centra hollow, with large lateral openings; sacral vertebræ solid, with lateral depressions in centra; caudal vertebræ solid; anterior caudals with flat articular faces, and transversely compressed neural spines; median caudal vertebræ with neural arch on front half of centrum. Ischia with compressed distal ends, and sides meeting on median line.

Genera *Pleurocœlus, Astrodon* (?). Jurassic, North America and Europe. Include the smallest known *Sauropoda.*

(5) Family *Cardiodontidæ.* Teeth of moderate size. Upper end of scapula expanded; humerus elongate; fore limbs nearly equalling hind limbs in length. Sacrum solid; ischia with wide distal ends and sides meeting on median line. Caudal vertebræ biconcave; median caudals with double chevrons.

Genera *Cardiodon* (Cetiosaurus), *Bothriospondylus, Ornithopsis,* and *Pelorosaurus.* European, and probably all Jurassic.

(6) Family *Titanosauridæ.* Fore limbs elongate; coracoid quadrilateral. Presacral vertebræ opisthocœlian; first caudal vertebræ biconvex; remaining caudals procœlian; chevrons open above.

Genera *Titanosaurus* and *Argyrosaurus.* Cretaceous (?), India and Patagonia.

4. *A New Theory of Retrogression.* *By* G. A. Reid.

5. *On the so-called Fascination of Snakes.* *By* Dr. A. J. Harrison.

The author stated that from observations he had made in the Zoological Gardens, Clifton, during many years, with regard to the fascination of snakes over their victims, he had come to the conclusion that such power did not exist. He based his remarks chiefly upon investigations he had himself made upon snakes in the Gardens, mostly the python and the boa constrictor. These researches were divided into three groups: (1) general, extending over many years; (2) more particular ones, personal, and in the presence of friends, or not; and (3) those of other and distinct observers.

The very names the ancients gave to the larger snakes, the history of the basilisk, the direful properties and extraordinary magnitudes which they attached to them, all worked upon the imagination, and prepared the mind for marvels; these strange ideas are for all time crystallised, so to speak, in that magnificent work of art Laocöon and his sons being destroyed by enormous serpents.

With regard to the first set of observations, the author related instances where rabbits, ducks, fowls, or rats have been placed in snakes' cages when the animals were inclined to feed, and yet the victims evinced no fear; sometimes they even attacked the snakes. Under the second heading more minute observations were given, which were often made in the presence of other persons. The description of a python when 'on his feed' was given, his increased activity and brightness of his stony and lidless eyes, slight rise of temperature, the opening and gaping mouth; and when these conditions were well fulfilled, the victims, when placed in the cage, did not seem to evince any alarm, and certainly were not overcome by the fascinating spell. On the other hand, if the prey was not at once seized, as not unfrequently happened, the duck, or the rat, or the fowl, or the rabbit might even attack the snake, and for a time almost reverse the position of victim and victimiser. When the snake did attack the onslaught was surprisingly sudden and very subtle.

The author then quoted the experiences of other observers, Mr. C. T. Buckland, Miss Catherine Hopley, Dr. Clement Stead, the brothers Hagenbeck, of Hamburg, Jamrach, a large London dealer, and several others. The evidence of all these was opposed to any theory of fascination.

In conclusion he related some recent observations which he had made on twenty-two young boas born in the Gardens.

6. *On the Scientific Experiments to Test the Effects of the Closure of Certain Areas in Scottish Seas.* *By* W. C. McIntosh, *F.R.S.*

In this paper the subject is dealt with under three heads, viz.—(1) The Results of the Investigations in St. Andrew's Bay; (2) those in the Firth of Forth; and (3) those in the Moray Firth.

In order to ensure uniformity of treatment, and to make every source of information available, the statistical tables were prepared on the same lines as those for the Trawling Commission under Lord Dalhousie (1883–85).

In glancing at the averages for the period in St. Andrew's Bay the closure is shown to have produced no increase of the food-fishes. On the contrary, the report of the Fishery Board, under whom the experiments in the 'Garland' were carried out, labours to prove that a diminution has taken place, and therefore a further closure, in extra-territorial waters, is called for. This opinion is based on a contrast of the first five years of the decade with the last five years. But, if a map is made of the months during which the hauls took place in the first period (1886–1890), it will be found that they are thickly dotted in the months of August and October, and have a preponderance in September. On the other hand, the second quinquennial period is handicapped by frequent examinations in the colder months, which, while increasing the hauls, seriously affect the averages. The so-called diminution is shown to be due not to a diminution of fishes in the period, but to the less successful capture in the colder months. The conditions of the two quinquennial periods were wholly divergent, for in the first there was a balance of 38 in favour of the hauls in the warmer months, and in the second one of 23 in favour of those in the colder months.

In the case of the Firth of Forth the proportions of the hauls in the warmer and in the colder months quite differ from that of St. Andrew's Bay in the respective quinquennial periods. In the first there were no less than 50 in favour of the six warm months, and only five in favour of the colder months in the second period—that is to say, out of 269 hauls in the first period 159 occurred during the warmer months (May to October) and 110 in the colder months, whilst in the second 214 occurred in the warmer and 219 in the colder months. Here likewise no sign of substantial increase followed the closure, though the food-fishes maintained their ground. One instance will suffice, and it is of a form which is stated by many to be 'swept out' of the Forth—viz. the haddock. Moreover, it shows the complex nature of such an inquiry. During the last year of the 'Garland's' work in the Forth 7,033 haddocks, or 93 per haul, were captured, which, contrasted with 1887, showed a reduction of 36 per haul, and therefore ostensibly forms a basis for demanding further closures, so as to control the 'spawning grounds' of the parent fishes, which are devastated by trawlers and general free fishing in the open waters. But the work in 1887 was carried out only in the months of June, August, and September, all productive months, whereas in 1895 the work ranged over ten months, five being warmer and five being colder, a very different condition. If we take the captures of the haddock during the colder months of this period—viz. 435, and contrast them with those of the warmer— viz., 6,598, the force of this criticism is apparent. There were actually more per haul—viz. 157—in these five warmer months than in the very favourable three months in 1887—viz. 129. Hesitation is, therefore, felt in approving of a method of controlling the important subject of the fisheries of the country which does not appreciate the available sources of information.

On the whole, the food-fishes of the Forth remained at the end of the experiments very much as they were at the beginning, just as happened in the case of St. Andrew's Bay.

Comparatively few trawlers worked in the Moray Firth in 1884. At that time three hauls of a commercial trawl on Smith Bank and off Caithness, in April, gave a total of 2,711 saleable fishes, or 903 per haul, a very moderate number in contrast with some of those off the Forth the same season, each of which produced from 1,500 to 2,744 saleable fishes. The average size of the haddocks in the Moray Firth was noteworthy, for few of the kind termed small were procured. The average number per haul was 604, or next to the Forth in this respect. The avidity with which trawlers sought the region subsequently, the captures by the liners up to a recent date, and the work of the 'Garland' sufficiently deal with the groundless views about the Moray Firth being 'swept out.' Moreover, on April 7 and 8 of this year (1898) six hauls in a commercial trawler were made outside the limits of the protected area, resulting in a total of 5,286 fishes, or 881 per haul, a contrast to the indifferent work of the 'Garland' within it. The chief fish, as in the former case, was the haddock, and it was satisfactory to find that in the midst of an area worked by 12 to 20 trawlers the average of this important fish was 695, or 91 over the average within the protected area in 1884. Without going into further detail at present it may be remarked in passing that the distribution of this species is so wide, and its numbers so great, that a survey of the whole subject leaves little room for doubt as to the wisdom of removing all unnecessary restrictions from fair fishing. Further, no trace of any effect of the closures on this fish is apparent, either here or in any of the other areas. Such a gigantic step as the closing of the whole Moray Firth is at variance with the principles which in 1884 caused the recommendation for the closure of the Forth, St. Andrew's Bay, and Aberdeen Bay for *experimental purposes* to be made. Step by step every available argument has been examined, and no scientific basis remains on which to uphold such a proposal.

The conclusions, therefore, briefly are:—

1. That the haste for additional closures (to the original areas of the Forth, St. Andrew's Bay, and Aberdeen Bay), after a year or two's work, and before any definite scientific result could be obtained, was unnecessary.

2. That no increase of the food-fishes has followed the closure, the high and low numbers succeeding each other in such a way as can only be explained by the irregularities and uncertainties invariably attendant on fishing operations.

3. That, because the first five years of the decade had a higher average than the second, it therefore followed that diminution of the fishes had occurred, and called for further closures beyond the three-mile limit to remedy it, is shown to rest on insecure data.

4. That the closure of the Moray Firth cannot be supported on scientific grounds.

5. That the closure of the three-mile limit, or even the thirteen-mile limit, can have little effect on a plan so gigantic as the distribution of invertebrates and fishes in the ocean.

6. That the interference of man—specially by closure on the one hand—is powerless to increase the food-fishes of the sea, or, on the other hand, by eager fishing, to reduce them to vanishing point.

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7. *On a Circulatory Apparatus for Use in Researches on Colour Physiology and other Investigations. By* F. W. KEEBLE, *M.A., and* F. W. GAMBLE, *M.Sc., Demonstrators in Owens College, Manchester.*

In a research on the colour physiology of certain marine crustaceans (*Virbius varians*, &c.) we have found it necessary to devise an apparatus which shall allow of the passage of a constant current of sea water through a number of observation dishes so arranged in series that any one may be disconnected without interrupting the flow through the others.

The constancy of flow is effected by fitting the aspirator bottle, the water reservoir, with a pressure tube and an exit tube beginning with a very fine point. The water is siphoned through the observation chambers and escapes at a point indicated in the diagram which was exhibited to the Section. At the outset we find our attention directed to the question as to whether change in the aëration of the water or change of the water itself is the more efficacious in maintaining the animals in a healthy condition. For this purpose we connect with our main apparatus another set of observation dishes, also arranged in series, and through which air is drawn by the aspirator, the content of which is such as to allow the current to run uninterruptedly at a fair rate for twelve hours or more.

By using a series of observation dishes in each case we are able to compare the effects of diffuse light, darkness, and monochromatic light on the colour, and on the chromatophores of the animals submitted to the experiment.

Monochromatic light is obtained by the use of colour-filters which we have constructed somewhat on the model of Landolt's 'Strahlenfilter,' and which fit closely on our observation dishes, the sides of which are darkened.

The 'colour-filters' are made of two- or three-chambered vessels containing appropriate fluids in exactly requisite thicknesses.

For the further examination of the immediate effects of light, darkness, and monochromatic light we employ a horizontal microscope fitted with a 'live box' which can be connected to the water circulation and below the stage with a colour-filter.

On the conclusion of the light experiments referred to, we intend to examine the effects of gases and of anæsthetics, &c., on the nervous system and the chromatophores.

This apparatus, though devised for the research on colour physiology, is one which, we venture to think, is likely to prove of some value in cognate researches, some of which we hope subsequently to undertake.

The experiments have entailed some considerable expense, and to continue the work a duplicate apparatus is necessary. We therefore venture to apply to the General Committee of the British Association for a grant of 15*l.* in aid of this research.

TUESDAY, SEPTEMBER 13.

The following Papers and Reports were read:—

1. *On Musical Organs in Spiders. By* R. I. POCOCK.

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2. *On the Origin of the Vertebrate Notochord and Pharyngeal Clefts.*

By A. T. MASTERMAN, *B.A.*, *D.Sc.*

The three leading anatomical features of the *Chordata* are usually represented to be the dorsal nervous system, the notochord, and the pharyngeal clefts. Of these the first does not stand out so distinctly as do the others, because in the great majority of the invertebrate phyla there is found a certain important portion of the nervous system, *i.e.* the supra-œsophageal ganglion, which has a dorsal position relative to the gut.

The other features are not in any way characteristic of other phyla, and are conspicuous alike in their morphological and ontogenetic features.

Morphologically the notochord and the pharyngeal clefts have little in common. Both are absent in the adult *Amniota,* and both take a more prominent part in the constitution of the lower vertebrates than that of the higher.

Ontogenetically they both arise from the same layer, *i.e.* the hypoblast, and first appear as local hypertrophies of the alimentary canal, taking the form of diverticular outgrowths, which differ in that whilst the notochord, in the higher forms, becomes completely separated from the parent layer, the pharyngeal pouches come into contact with the epiblast, and eventually (in most) acquire an opening to the exterior. The inference from these morphological characters is that both the notochord and pharyngeal clefts have in the early history of the vertebrate animals played a far more prominent part in their structure than at present.

In the case of the notochord, those of the true *Chordata,* in which it does not disappear in the adult, seem to make use of this organ as an elastic axile support intimately connected with the myomeric muscles and the mode of locomotion adopted by the aquatic chordates.

At the same time a little consideration will lead us to believe that the assumption that this is the primary function of the notochord will in no way explain the facts either of morphology or of ontogeny.

In the ontogeny of the notochord it is clearly derived, as already stated, from the hypoblast, and only secondarily in the process of development does it move away from its parent layer and take up a median axial position for the supporting function. No theory yet suggested takes sufficient account of this peculiar origin, which is unique for organs of support.

The legitimate inference is that the primary function of the notochord was directly connected with the endoderm and, in all probability, with the function of alimentation.

The morphology of *Amphioxus* and that of the *Tunicata* sheds no further light on the question, but there are certain forms which, mainly for the reasons here referred to, may be placed together in one group, *Archi-chorda,* which present in their adult anatomy various conditions of the notochord which correspond to the ontogenetic stages of the same organ in the higher *Chordata.*

Thus in *Balanoglossus, Cephalodiscus,* and larval *Phoronis* certain parts of the alimentary system are formed into diverticula, the cells of which are metamorphosed into chordoid tissue closely resembling that of the notochord. These structures, occurring as they do in forms which reveal more and more intimate resemblances to the higher *Chordata* with the progress of research, have the same relationship throughout life to the alimentary canal (pharynx) that the vertebrate notochord has to the same organ in the young stages of the higher *Chordata*.

For this reason they are accepted by some morphologists as organs homologous to the notochord, but exemplifying a more primitive condition of the same. To those who will not accept this conclusion their resemblance to the vertebrate notochord must appear as a most remarkable instance of convergent evolution occurring in animals which in many other respects show close genetic relationship. If, however, we accept this view we are led to ask the question, Does the study of these chordoid structures throw any further light upon the primary origin and function of the notochord?

In *Balanoglossus* the function of the so-called notochord is usually assumed to be that of support to the proboscis and its muscles, so that it appears to have already acquired that secondary function of support to the mesodermic tissues which, in the higher *Chordata*, leads to its eventual loss of connection with its parent tissue.

In *Cephalodiscus*, however, the two pleurochords run as dorso-lateral chordoid grooves throughout the length of the pharynx. Posteriorly they arise at the commencement of the œsophagus, and anteriorly they curve round to left and right to open to the exterior by two apertures, one on each side of the mouth. These apertures have been identified as pharyngeal clefts, and will be referred to again later. The actual function of the pleurochords in *Cephalodiscus* is, by the nature of the case, incapable of demonstration, but the further structure of the pharynx gives a clear indication of their use.

In *Ammocœtes*, in *Amphioxus*, and in the *Tunicata* a system of glands and ciliated grooves, comprising in its full development a subneural gland, an endostyle, a peri-pharyngeal band and hypobranchial groove, has been demonstrated. This system varies in its lesser details in the types mentioned, but its constant occurrence indicates clearly that the gnathostomatous condition of the *Vertebrata* was preceded by a method of feeding which depended on the ingestion of microscopic food suspended in water currents and the subsequent separation of the former from the latter. A similar system can be demonstrated in *Cephalodiscus*, the organ formerly described as a notochord being the subneural gland, connected by a well-defined peripharyngeal groove with the ventral alimentary portion of the gut, which itself can, through *Balanoglossus*, be homologised with the endostyle. The whole structure of the pharynx points to the conclusion that, whilst these organs serve to collect the food particles and carry them through the œsophagus to the stomach, the pleurochords serve to conduct the water current forwards and eventually outwards by the pharyngeal clefts. In other words, the notochord of the vertebrates has arisen from the endoderm, as a certain specialised area of the alimentary canal, which, becoming stiffened by a chordoid metamorphosis, serves as an organ for the removal of the water current involved in the ciliary ingestive processes.

According to this hypothesis the hypoblastic origin of the notochord, no longer a difficulty, becomes a phyletic repetition of the same nature as the epiblastic origin of the nervous system.

In the case of the pharyngeal clefts Dr. Harmer has already pointed out that in *Cephalodiscus* they serve, in all probability, for the discharge of 'atrial' water, and it has been shown above that they are morphologically merely the openings of the pleurochords to the exterior. In this species there is no indication that they function for respiration. They are kept open by chordoid walls, and have the same relation to the pleurochords as has the anus to the alimentary canal. The hypoblastic origin of a gill slit is thus explained in the same way as that of the notochord, and the primary origin of the two has a similarity almost amounting to identity. The pharyngeal cleft, like the notochord, later on in the history of the *Chordata*, loses its primary atrial function and becomes a branchial gill slit. Just as the notochord is eventually replaced by mesoblastic supporting tissue, so the chordoid walls of the pharyngeal cleft give place to mesoblastic branchial arches.

The *Echinodermata* are a group which have long been under suspicion as connected with the genealogy of the *Vertebrata.* A large proportion of them have free-swimming pelagic larvæ, which feed by ciliary ingestion. If the processes of ingestion be followed by feeding early *Bipinnaria* in the laboratory, the food particles may be seen to pass down the ventral part of the so-called œsophagus and to accumulate at its inner end. They are then periodically injected through the small aperture into the 'stomach.' The ventral groove has already been compared by Mr. Garstang to the endostyle of *Tornaria* and to that of the other *Chordata.*

On the other hand, the water current, after passing down the gullet, returns along the dorsal part and is discharged to the exterior by a pair of lateral grooves which become very marked in later larvæ. This dorsal part is kept open by the arched roof of the gullet, the cells of which exhibit a histological structure closely approximating to that of the typical chordoid tissue. Bearing in mind the other features in which the *Echinodermata* are acknowledged to resemble the *Chordata,* there seems ground for homologising this dorsal chordoid element of the larval gullet with the notochord of the latter group, and the two lateral grooves with the pharyngeal clefts. They apparently represent an even more primitive stage of these organs than is found in *Cephalodiscus,* in which the chordoid organ has apparently diverged into two and the atrial grooves have become definite clefts.

Briefly, then, the phyletic history of the vertebrate notochord and gill slits may be summed up as follows. In the pelagic ancestor of the *Chordata* the gut was undifferentiated, and the food and water were alike washed through its course. An early constriction between pharynx and stomach resulted in the exclusion of the water current from access to the latter, and the consequent return of the same along the dorsal part of the former. In relation to this the cilia became confined to the ventral part, eventually giving rise to the endostyle, whilst the dorsal part, supplied with 'atrial' water alone, became modified into the notochord. Under conditions of insufficient nutrition the constituent cells of this area lost their cilia, and, undergoing a retrogressive metamorphosis, they became a mass of vacuoles and cells with little, if any, residual protoplasm; between the two portions of the gullet so formed there appeared the lateral 'atrial' grooves. Such a condition is exhibited in echinoderm larvæ.

In such a form as *Cephalodiscus,* where the original functions persist, the notochord, retaining its connection with the 'atrial' apertures, divides into two, but in the direct line of chordate descent it remains single.

Further differentiation leads eventually to the separation of the notochord dorsally, and that of the endostyle (or thyroid) ventrally, from the pharynx, whilst, at the same time, the atrial grooves become transformed into pharyngeal clefts (or gill slits).

Such a hypothesis, in attempting to account for the origin of notochord and of gill slits, agrees fairly with the facts of morphology and ontogeny, although it can in no way be regarded as entirely conclusive.

3. *Le Développement du Cœur chez les Tuniciers: Quelques Considérations sur la Phylogénié des Ascidies simples.* *Par* Professeur CH. JULIN.

4. *Demonstration of Dr. Field's Card-catalogue of Zoological Literature.*

By W. E. HOYLE.

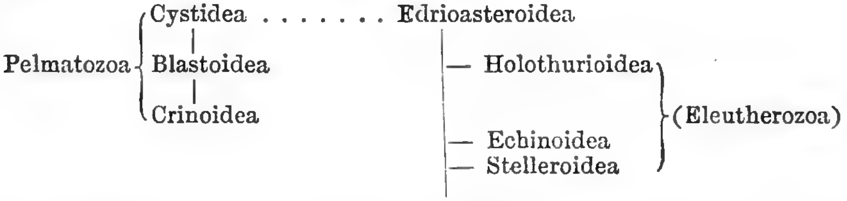
5. *A Phylogenetic Classification of the Pelmatozoa.*

By F. A. BATHER, *M.A., F.G.S.*

The classification is an epitome of that adopted in a forthcoming text-book of zoology edited by Professor Ray Lankester. The standpoint is phylogenetic, and is based on the following beliefs.

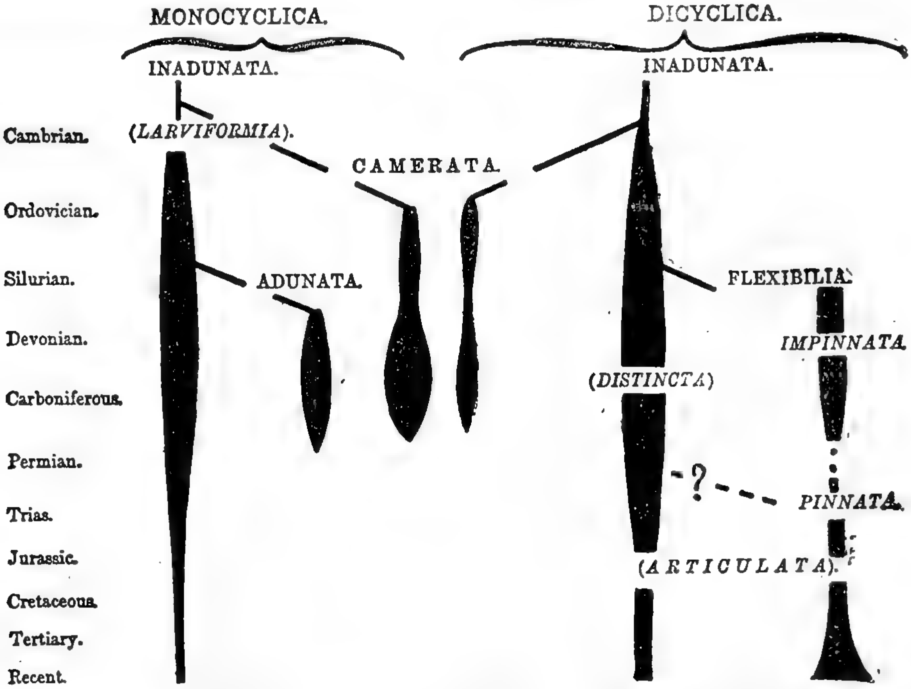
The Pelmatozoa represent a grade of structure passed through by the ancestors of all echinoderms in their passage from the bilaterally symmetrical Dipleurula stage to the radiate stage. The essential feature was fixation by the primitive oral (anterior) end, followed by the upward passage of the mouth. The foregut in that passage involved other organs of the primitive left side, especially the left anterior cœlom and its offshoot the left hydrocœl. The primitive pelmatozoon had not acquired radiate symmetry. This was induced by the extension from the central upwardly directed mouth of ciliated food-grooves (subvective system of Hæckel). The presence of anus and hydropore on the oral surface forbade absolute symmetry of extension; hence the primitive number of grooves was three—one anterior away from the anus, one right, and one left. Bifurcation of the right and left grooves produced the number five, as now we see it. It was after the pelmatozoan type of structure had been attained that some forms again relinquished the attached mode of life, and assumed a position with the mouth anterior, as Holothurians, or with it downwards, as Stelleroidea and Echinoidea. In the torsion of their internal organs, in the pentamerous symmetry, and in other details, all these forms bear the mark of their pelmatozoan ancestry. This need not mean that they were descended from any pelmatozoan genera with which we are acquainted, although the Edrioasteroidea certainly do present features in the structure of the subvective grooves which enable them to be compared with the primitive Echinoidea and Asteroidea. These features cause the separation of the Edrioasteroidea as a distinct Class, a step already taken by Billings, Huxley, Chapman, Worthen, Steinmann, Jækel, and others. The Holothurians, Stelleroids, and Echinoids may be grouped together as Eleutherozoa, without implying any genetic connection between them further than that due to their independent descent, at different periods, from pelmatozoan ancestors. Between the latter, however, the connection is so evident that it should be recognised by the retention of them in a sub-phylum Pelmatozoa.

The mutual relations of the Classes are thus conceived, the older being placed at the top:—



The starting-point of the Cystidea is a simple, many-plated, sac-like form, the skeleton of which presents no trace of radial subvective or ambulacral systems; the porous structure of the stereom is indefinite, and no stem is differentiated. Hæckel's Order Amphoridea is adapted to include this and such modifications of it as did not attain radiate symmetry. Further modifications of this type depend on the mode of extension of the subvective system. In one group these extensions pass over the thecal plates (epithecal), while still further extensions arise from the grooves on 'exothecal' processes (brachioles). In the other group exothecal brachioles spring at once close to the mouth. These two types are in the main correlated with two gradual differentiations of stereom structure. In the former the simple or irregular haplopores become connected in pairs (diplopores). In the latter the pore-canals come to lie parallel to the surface of the test and at right angles to the sutures between the plates (pore-rhombs). These canals really represent stroma-strands, and sometimes, perhaps, hæmal lacunæ; there were no true pores. Enlargement of the thecal plates emphasised this rhomb-structure, since it added strength to the plates. Diminution in size of the thecal cavity and pressure of the coiled gut against its walls concentrated these structures in definite areas, while the need for compensating this restriction of the assumed respiratory area led to the specialisation of the remaining pore-rhombs as 'pectini-rhombs.' These facts justify the Orders Diploporita and Rhombifera, and leave only a few Cystidea in the provisional Order Aporita. In none of these forms has the radial symmetry of subvective and ambulacral systems induced completely correlated symmetry in the theca. The Diploporita, however, tend gradually and clearly in this direction, and lead imperceptibly to the Blastoidea. Either the Blastoidea, as hitherto understood, must be placed with Cystidea, or their limits must be enlarged to include such Diploporita as have this definite correlation and plates that can be called 'radials.' The latter course enables us to define the Cystidea with greater precision, and is therefore adopted.

The Blastoidea, therefore, have to be divided into two grades—Protoblastoidea and Eublastoidea. The classification of the latter into Regulares and Irregulares is no statement of genetic affinity. Moreover, Etheridge and Carpenter's families of the Regulares are based almost entirely on the relations of the hydrospire-canals to the deltoids, relations which may vary considerably even in an individual. Renewed study of the relations of the hydrospires to the ambulacra, of persistent peculiarities of ornament, and the affinities of individual genera, suggests that there were three lines of development arising from *Codaster*, *Troostocrinus*, and *Nucleocrinus* respectively. Stages in the evolution of these lines determine the establishment of families.



Supposed Relations of the Orders and Sub-Orders of Crinoidea.

From forms that had acquired pentamerism of the theca, and that, apparently, possessed hydrospires, the Crinoidea were differentiated by the evolution of true brachia. These in their origin are not exothecal, but actually thecal, and bear along with them epithecal branches of the subvective system, but not brachioles. Such a form is *Hybocystis,* Wetherby non Benson. The many-branched and pinnulate arms, the simple and definite calycal system, or the compound and indefinite cup, the plateless or the vaulted tegmen, can all be traced back to such a simple ancestor through actual known genera. The sole gap that cannot be bridged within the limits of the Crinoid class is that between the monocyclic and dicyclic base. The history of these two divisions is shown in the annexed diagram, from which, if it be a true presentment, it appears that the Orders previously accepted are polyphyletic, and are statements of convergent structure, not of affinity. It is, however, well to accept existing terms so far as possible.

Dividing all Crinoidea into *Monocyclica* and *Dicyclica*, we trace in each Order a gradual and, to some extent, parallel modification, here and there diverging in somewhat similar directions. Thus the simplest forms in each Order are *Inadunata*, with free distinct arms, and pass from a Larviform stage, with simple tegmen, to a Fistulate stage, with more complex anal tube and tegmen. At an early period (? Cambrian) in the history of the Monocyclica, the Camerate modification—viz., rigid incorporation of brachials in cup and ambulacrals in tegmen—affected a few forms, and thus arose *Monocyclica Camerata*. At a later period (Silurian) was a repetition of this modification, but one affecting the cup to a far less extent, and resulting chiefly in a solid tegmen and biserial arms; thus arose the *Monocyclica Adunata* (or Platycrinoidea), which even Wachsmuth and Springer find a difficulty in placing with the Camerata. These two highly specialised branches died out before the close of the Palæozoic epoch, the Adunata outliving the Camerata; but the simpler Inadunate forms continued, and reached a high degree of specialisation in their Jurassic descendants, to which the living *Hyocrinus* is closely related. The Dicyclica Inadunata similarly gave off the *Dicyclica Camerata*, which persisted only a little less long than their monocyclic convergents. The dicyclic Crotalocrinidæ of the Silurian are curiously parallel to the Monocyclica Adunata, but it is not worth while to separate them from the typical Inadunata. About the same time arose among the dicyclic Inadunata the modification that resulted in the *Flexibilia*, with brachials loosely incorporated in dorsal cup. The dicyclic Inadunata came to their acme in Carboniferous times: their arms were then 'distinct,' and only those forms persisted to Neozoic and Recent periods which assumed an Articulate modification—viz., a loose lateral union of proximal brachials, as seen in Pentacrinidæ, which are convergents of the Neozoic Flexibilia. The latter Sub-Order was represented during Palæozoic times by the Ichthyocrinoidea (Impinnata). Between them and the Neozoic Apiocrinidæ, Bourgueticrinidæ, &c. (Pinnata), the links are missing, but may yet be found among Permian and Triassic crinoids (*vide supra*). At any rate, the Neozoic Flexibilia, when they assumed the free-swimming habit, took a new lease of life and have their acme in our own day.

On the foregoing principles and beliefs, along with many others related in the book itself, is based the following classification of Pelmatozoa:—

SUB-PHYLUM PELMATOZOA.—Theca calcified and plated; oral surface uppermost, usually attached temporarily or permanently by aboral surface. Food brought to mouth by ciliated grooves, which may be endothecal (*i.e.*, between the plates), epithecal, exothecal, or, in part and secondarily, hypothecal. Anus usually in upper half of theca, never aboral. An aboral nerve-centre co-ordinates the movements of the whole skeleton. Hydrocircus communicates indirectly with exterior; podia, when present, respiratory, not locomotor.

Class I. CYSTIDEA.—Radial polymeric symmetry of theca developed either not at all, or not in complete correlation with radial symmetry of ambulacral and subvective systems. The latter is exothecal or epithecal, not endothecal.

Order 1. AMPHORIDEA.—Radial symmetry has affected neither food-grooves nor thecal plates, nor, probably, nerves, ambulacral vessels, nor gonads.

Fam. *Aristocystidæ*. No extension of food-grooves on theca or skeletal processes; thecal plates irregular, unspecialised; no stem. *Dendrocystidæ*. Single oral skeletal process; thecal plates irregular, merging gradually into stem. *Anomalocystidæ*. Theca compressed in plane of thecal apertures; the plates of the two sides inclosed by a common frame of marginals; food-grooves conveyed on spines, one at each upper angle of theca; no pores.

Order 2. RHOMBIFERA.—Radial symmetry affects food-grooves, and (in more advanced families) thecal plates; probably also nerves and ambulacral vessels, but not gonads. Food-grooves exothecal, the brachioles being either close to mouth, or removed from it on a series of subambulacrals not derived immediately from thecal plates, or separated from it by hypothecal passages. Stereom and stroma become arranged in folds and strands at right angles to sutures.

Fam. *Echinosphæridæ*. Thecal plates numerous, indefinite, with pore-rhombs. Brachioles circumoral, unbranched. Columnals not uniserial. *Comarocystidæ*.

Thecal plates numerous, indefinite, with strong radial structure of stereom, but no pore-rhombs. Brachioles branched; columnals uniserial. *Macrocystellidæ.* Thecal plates in three or four circlets, subject to somewhat regular pentamerism, with radiately folded stereom, but no pores. Brachioles borne by upper circlet. *Tiaracrinidæ.* Plates forming sides of theca are in not more than two circlets; with strong transverse pore-rhombs in each circlet. *Malocystidæ.* Thecal plates numerous, indefinite, radiately folded, no rhombs. Food-grooves on exothecal processes pass over theca and bear brachioles. *Glyptocystidæ.* Theca of five circlets of alternating plates, typically five in each circlet; but in aboral circlet r. post. and r. ant. plates are always fused. Anus between second and third circlets in r. post. interradius. Hydropore in adoral circlet, opposite unpaired food-groove, defines post. IR. Pectini-rhombs present, one always uniting l. post. plate of first aboral row with l. ant. plate of second row. Food-grooves, bordered by plates derived from proliferation of adoral circlet, pass over theca and bear biserial brachioles. (Sub-famm. *Echinoencrininæ*, *Callocystinæ*, *Glyptocystinæ*.) *Caryocrinidæ.* Thecal plates primitively in four circlets, dominated by trimerous symmetry, and united by pore-rhombs. Food-grooves in adoral region are hypothecal, then for a short space epithecal, and distally exothecal and brachioliferous.

Order 3. APORITA.—Pentamerism affects food-grooves and thecal plates, probably also nerves and ambulacral vessels, but not gonads. Food-grooves exothecal and circumoral. No folds, pores, or rhombs.

Fam. *Cryptocrinidæ.* Thecal plates in four circlets.

Order 4. DIPLOPORITA.—Radial symmetry affects food-grooves, and by degrees the thecal plates connected therewith, but not interradial plates; probably also nerves and ambulacral vessels, but not gonads. Food-grooves epithecal (without intermediary of subambulacrals), also prolonged on exothecal brachioles, which line the epithecal grooves. Stereom may be folded, but pore-rhombs not developed; diplopores always present in mesostereom, but restricted in distribution in higher forms.

Fam. *Sphæronidæ.* Food-grooves do not extend beyond adoral circlet. Diplopores diffuse. *Glyptosphæridæ.* Food-grooves extend beyond adoral circlet, and irregularly transgress sutures between thecal plates. Diplopores diffuse. *Protocrinidæ.* Food-grooves extend almost to aboral pole, and are regularly bordered by alternating thecal plates (adambulacrals), which bear brachioles. Diplopores diffuse or confined to adambulacrals, from which they are never absent. *Mesocystidæ.* Food-grooves extend almost to aboral pole, bordered by alternating brachioliferous adambulacrals raised above interambulacrals. Diplopores confined to interambulacrals. Five interradial deltoids (Δ) surround peristome. *Gomphocystidæ.* Food-grooves curve around theca; no brachioles.

Class II. BLASTOIDEA.—Five (by atrophy four) epithecal food-grooves, lying on a lancet-plate (? always), pass between five Δ, and are bordered by alternating, brachioliferous adambulacrals. Peristome and all grooves have covering plates. No extensions from gonads and cœlom along rays into brachioles; but, apparently, nerves from aboral centre met in circumoral ring, whence branches passed beneath food-groove and supplied brachioles. Basals (B) and radials (R) always defined; sutures of thecal plates never cross the subvective areas.

Grade 1. PROTOBLASTOIDEA.—Thecal plates indefinite in number; no hydrospires. Fam. *Asteroblastidæ* (*Asteroblastus*, *Steganoblastus* [?], *Blastoidocrinus*).

Grade 2. EUBLASTOIDEA.—Thecal plates definite, in three circlets, viz., 3 BB, 5 RR, 5 Δ. Stereom of RR and Δ, on either side subvective areas, thrown into folds running across radio-deltoid suture (hydrospires).

Series *Codonoblastida.*—Fam. *Codasteridæ* (Eth. and Carp.). Hydrospire-folds distinctly portions of the thecal plates, coming to the surface of the radial sinus. No distinct hydrospire-canal or pores; spiracles developed imperfectly or not at all. (*Codaster*, *Phænoschisma*, *Cryptoschisma*, *Orophocrinus*.) *Pentremitidæ* (Eth. and Carp. restr.). Hydrospire-folds, usually numerous, concentrated at the lowest part of the radial sinus, and partly or wholly pendent. Hydrospire-canal opens through spiracles bounded distally by side-plates. Base convex. Ambulacra rather broad. (*Pentremitidea*, *Pentremites*.)

Series *Troostoblastida.*—Fam. *Troostocrinidæ* (Eth. and Carp.). Elongate forms with linear ambulacra descending sharply outwards from the much restricted peristome. Hydrospire-folds only slightly concentrated, but communicate with exterior through pores, and through spiracles bounded by Δ and lancet-plates. (*Troostocrinus, Metablastus, Tricœlocrinus.*) *Eleutherocrinidæ.* Elongate, stemless, asymmetrical, with four narrow ambulacra, accompanied by unconcentrated hydrospires. Fifth ambulacrum shortened and widened. Δ minute. (*Eleutherocrinus*).

Series *Granatoblastida.*—Fam. *Nucleocrinidæ.* Interambulacra show traces of a primitive three plates. Ambulacra linear, and stretching far down the theca, which is ovoid. Hydrospire-folds few and pendent. Spiracles double. Mouth roofed by large plates firmly united into a tegmen. (*Nucleocrinus, Schizoblastus.*) Equals Nucleoblastidæ (E. and C.) *minus Cryptoblastus* and *Acentrotremites. Orbitremitidæ.* Theca globular with concave or flattened base. Ambulacra linear, stretching down to concavity of base. Hydrospire-folds few and pendent; a hydrospire plate always present (unknown in *Heteroblastus*). Hydrospire-folds rarely penetrate Δ, but long canals pass onward, through, beside, or under them, except in *Acentrotremites.* (*Orbitremites, Cryptoblastus, Heteroblastus, Mesoblastus, Acentrotremites*). Corresponds to Granatoblastidæ (E. and C.) *plus Cryptoblastus, Mesoblastus,* and *Acentrotremites. Pentephyllidæ.* Theca subpentagonal, stemless; RR asymmetrical. Ambulacra linear, stretching down to base. One shorter than the rest. (*Pentephyllum.*) *Zygocrinidæ.* Theca depressed, stemless, asymmetrical, quadrilobate. Four ambulacra between the lobes, accompanied by a single hydrospire on either side. Fifth ambulacrum shortened and widened. Δ large. (*Zygocrinus.*)

Class III. CRINOIDEA.—Epithecal extensions of the food-grooves, ambulacrals, superficial oral nervous system, blood-vascular and water-vascular systems, cœlom, and genital system are continued exothecally upon jointed outgrowths of the abactinal thecal plates (brachia), carrying with them extensions of the abactinal nerve system. Brachia, primitively and normally five, always rise from an equal number of thecal plates, 'radials' (RR). Below these is always a circlet, or traces of a circlet, of interradial plates, called 'basals' (BB). A circlet of radially situate 'infrabasals' (IBB) may also be present.

Sub-Class A. MONOCYCLICA.—Base consists of BB only; aboral prolongations of chambered organ interradial; new columnals introduced at extreme proximal end of stem.

Order 1. INADUNATA.—Dorsal cup is confined to the patina and occasional intercalated anals; such Amb or iAmb as enter the tegmen remain supra-tegminal, and not rigidly united.

Famm. *Hybocrinidæ* (incl. *Hybocystis,* Wetherby), *Stephanocrinidæ, Heterocrinidæ* (incl. *Herpetocr.*), *Calceocrinidæ, Pisocrinidæ, Catillocrinidæ, Zophocrinidæ, Haplocrinidæ, Allagecrinidæ, Symbathocrinidæ* (incl. *Phimocr., Stortingocr.*), *Belemnocrinidæ* (incl. *Missouricr.*), *Plicatocrinidæ, Hyocrinidæ, Saccocomidæ.*

Order 2. ADUNATA.—Dorsal cup primitively confined to the patina and an occasional single anal; tegmen solid; portions of the proximal Br and their Amb send to be rigidly incorporated in the theca. Arms fork once to thrice, and bear pinnules on each or on every other Br. BB fused to three, two, or one. (*Eucladocr.* and Acrocrinidæ offer peculiar exceptions to this diagnosis).

Group A. Fam. *Platycrinidæ*: Sub-famm. *Coccocrininæ* (incl. *Hapalocr., Cordylocr.*), *Cypellocrinæ* (*Cypellocr.* = *Marsupiocr.* Phill. non Blainv.), *Platycrininæ.*

Group B. Fam. *Hexacrinidæ, Acrocrinidæ.*

Order 3. CAMERATA.—IBr, two in each ray (exc. *Stereocr., Hadrocr., Alloprosallocr.*), and often succeeding orders of Br are incorporated by iBr in the dorsal cup, while the corresponding Amb are either incorporated in, or pressed below, the tegmen by iAmb; all thecal plates united by suture, somewhat loose in the earliest forms, but speedily becoming close, and producing a rigid theca; mouth and tegminal food-grooves closed; arms pinnulate.

Sub-Order *Melocrinoidea.*—RR in contact all round; IBr$_1$ quadrangular.

Famm. *Glyptocrinidæ, Melocrinidæ, Patelliocrinidæ* (incl. *Steliodiocr., Macrostylocr., Allocr., Briarocr., Centriocr.* [nom. mut. pro *Centrocr.* W. and Sp. non Austin nec Worthen]), *Clonocrinidæ* (incl. *Clonocr.* Quenst. [= *Corymbocr.* Ang.], *Trybliocr., Technocr.*), *Eucalyptocrinidæ, Dolatocrinidæ.*

Sub-Order *Batocrinoidea.*—RR in lateral contact, except in post. IR. Proximal anal heptagonal; IBr_1 quadrangular, exc. in Periechocrinidæ. Famm. *Tanaocrinidæ, Xenocrinidæ* (incl. *Compsocr., Abacocr.*), *Carpocrinidæ* (incl. *Acacocr. Desmidocr., Macarocr.*), *Barrandeocrinidæ, Cœlocrinidæ* (incl. *Cœlocr.* [= *Aorocr.*, W. and Sp.], *Dorycr., Agaricocr.*), *Batocrinidæ* (incl. *Hyperocr.*, M. and W. [s. *Uperocr.*] = *Lobocr.*, W. and Sp.), *Periechocrinidæ.*

Sub-Order *Actinocrinoidea.*—RR in lateral contact except in post. IR; proximal anal hexagonal; IBr_1 usually hexagonal; BB 3, equal, forming a hexagon. Famm. *Actinocrinidæ* (as in Wachsm. and Spr., exc. *Amphoracr.* which forms —) *Amphoracrinidæ.*

Sub-Class B. DICYCLICA.—Base consists of BB and IBB, the latter being liable to atrophy or fusion with the proximale, but the aboral prolongations of the chambered organ are always radial; new columnals may or may not be introduced at the proximal end of the stem.

Order 1. INADUNATA.—Dorsal cup primitively confined to the patina and occasional intercalated anals, no other plates ever occur between RR (Grade—Distincta); Br may be incorporated in the cup, with or without iBr, but never rigidly, and their corresponding Amb remain suprategminal (Grade—Articulata); new columnals introduced at extreme proximal end of the stem.

Sub-Order 1. *Cyathocrinoidea* have a fairly stout tegmen, in which five orals (Δ, sub-ambulacrals, interradials, consolidating apparatus, of authors) are usually conspicuous, helping to stiffen the tegmen, supporting the ambulacra on their adjacent edges, and inclosing but not covering the peristome; post.O frequently a madreporite; radial facet usually narrow, and arms distinct from dorsal cup, unbranched or simply dichotomous; none are known to attain the pinnulate stage, but the presence of pinnules would not in itself remove a genus from the Cyathocrinoidea. Famm. *Carabocrinidæ, Palæocrinidæ* (incl. *Porocr., Bactrocr.*), *Euspirocrinidæ, Sphærocrinidæ* (incl. *Parisocr.*), *Cyathocrinidæ* (incl. *Gissocr., Lecythocr.*), *Petalocrinidæ, Crotalocrinidæ, Codiacrinidæ* (incl. *Lecythiocr.*), *Cupressocrinidæ, Gasterocomidæ* (incl. *Scolocr., Achradocr., Hypocr.*).

Sub-Order 2. *Dendrocrinoidea* have a thin flexible tegmen, or the ventral surface almost entirely occupied by a large anal tube or ventral sack; orals inconspicuous or entirely atrophied in the adult; no madreporite; radial facet often wide, so that the distinctness of arms from dorsal cup is not maintained; arms dichotomous, the dichotomy often irregular, leading up to a pinnulate stage. Famm. *Dendrocrinidæ* (incl. *Merocr., Ottawacr., Homocr., Thenarocr.*), *Botryocrinidæ* (incl. *Gothocr., Mastigocr., Gastrocr., Rhadinocr., Goniocr., Atelestocr., Streptocr.*), *Lophocrinidæ, Scaphiocrinidæ* (incl. *Poteriocr., Woodocr., Zeacr., Coeliocr., Bursacr.*), *Scytalecrinidæ* (incl. *Decadocr.*), *Graphiocrinidæ* (incl. *Æsiocr., Delocr.* = *Ceriocr.* White non Desor), *Cromyocrinidæ* (incl. *Eupachycr., Agassizocr., Tribrachiocr., Phialocr., Ulocr.*), *Encrinidæ* (incl. *Stemmatocr., Erisocr.*), *Pentacrinidæ* (incl. *Dadocr., Holocr.*, and Sub-fam. *Pentacrininæ*), *Uintacrinidæ, Marsupitidæ, Bathycrinidæ?* (only *Bathycr.*).

Order 2. FLEXIBILIA.—Proximal Br incorporated in dorsal cup, either by their own sides, or by iBr, or by a finely plated skin, but never rigidly; plates may occur between RR. Tegmen flexible, with distinct Amb and numerous small iAmb; mouth and food-grooves remain suprategminal and open. Top columnal a persistent proximale, often fusing with IBB, which are frequently atrophied in the adult. Arms non-pinnulate (Grade Impinnata), or pinnulate (Grade Pinnata), but always uniserial.

Grade *Impinnata.*—All plates of the crown united by loose suture or muscular articulation. IBB three, the primitive right posterior remaining as the small unfused IB. Br united by waving sutures, often with patelloid plates. Arms isotomous, or rami may bear ramules on one or both sides, but no pinnules. Ventral groove wide and shallow; axial canal separated from it in proximal region. Five O, between which food-grooves pass to the mouth.

Famm. *Ichthyocrinidæ* (incl. *Pycnosaccus, Lecanocr., Cyrtidocr., Clidochirus, Mespilocr.*), *Idiocrinidæ, Taxocrinidæ* (incl. *Gnorimocr.* [genotype *Taxocr. expansus*, Ang.], *Anisocr. Homalocr.*), *Dactylocrinidæ* (incl. *Calpiocr., Lithocr.* [genotype *Forbesiocr. divaricatus*, Ang.], *Synerocr., Euryocr., Onychocr.*), *Sagenocrinidæ* (incl. '*Forbesiocr.*' *Agassizi*). Impinnata incertæ sedis: *Edriocr., Cleiocr., Rhopalocr.*

Grade *Pinnata*.—BB and RR united by close suture, RR and proximal Br by muscular articulation or syzygy; pseudomonocyclic; arms pinnulate and either simple or isotomous; axial canal separate from ventral groove throughout; Iax is generally IBr_2, rarely IBr_1; five O present in early stages and sometimes in adult, but usually atrophy; anals do not form part of the dorsal cup in the adult.

Famm. *Apiocrinidæ* (incl. *Calamocr.*), *Bourgueticrinidæ* (incl. *Mesocr. Rhizocr.*), *Antedonidæ* (incl. *Thiolliericr., Eudiocr., Promachocr.*), *Atelecrinidæ, Actinometridæ, Thaumatocrinidæ, Eugeniacrinidæ, Holopodidæ, Eudesicrinidæ.*

Order 3. CAMERATA.—All IBr and usually IIBr incorporated in the dorsal cup by iBr, at first loosely, but afterwards by close suture. IBB always the primitive 5. Arms pinnulate. A plate always between right and left posterior RR, resting on posterior B, and followed by others leading up to the anus. Mouth and ambulacra subtegminal.

Famm. *Reteocrinidæ* (only *Reteocr.*), *Dimerocrinidæ* (incl. *Ptychocr., Orthocr., Hyptiocr.*), *Lampterocrinidæ* (incl. *Siphonocr.*), *Rhodocrinidæ.*

Class IV. EDRIOASTEROIDEA.—Theca composed of an indefinite number or irregular plates, some of which are variously differentiated in different genera; no skeletal appendages; central mouth, from which there radiate through the theca five unbranched ambulacra, composed of a double series of alternating plates, sometimes supported by an outer series of larger alternating plates. Pores between (not through) the ambulacral elements, or between them and the thecal plates, permitted the passage of extensions from the perradial water-vessels. Anus in posterior interradius, on oral surface, closed by valvular pyramid. Hydropore (?) between mouth and anus.

Fam. *Agelacrinidæ.* Theca composed mostly of thin plates, flexible, attached temporarily or permanently by the greater part of the aboral surface; ambulacra confined to oral surface. (*Stromatocystis, Cystaster, Hemicystis, Agelacr., Streptaster, Lepidodiscus, Haplocystis, Discocystis.* Perhaps incl. *Cyclocystoides*). *Cyathocystidæ.* Theca composed on oral surface of five deltoids surrounded by marginals, but below of a fused solid mass of stereom, which forms a permanent incrusting root. *Edrioasteridæ.* Flexible theca of thin plates; loosely attached by excavate aboral surface; ambulacra pass on to aboral surface. (*Edrioaster, Dinocystis*).

6. *On the Detection of Phosphorus in Tissues.*
By Professor A. B. MACALLUM, *Ph.D.*

7. *Report on the Physiological Effects of Peptone and its Precursors when introduced into the Circulation.*—See Reports, p. 720.

8. *Report on Caves in the Malay Peninsula.*—See Reports, p. 571.

9. *Report on Nerve-cells.*—See Reports, p. 714.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—COL. G. EARL CHURCH.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

Argentine Geography and the Ancient Pampean Sea.

INSTEAD of addressing you upon geography as a science, or summarizing the triumphs of explorers during the past year, I shall invite you to accompany me to southern South America—a step towards the Antarctic regions—and let me try to add to your knowledge of Argentine geography and the ancient Pampean Sea.

The matchless voyage of Magellan gave rise to one, in 1526, for the discovery of 'the Islands of Tharsis, Ophir, and Eastern Cathay,' the command of which was given by Charles V. of Spain to Sebastian Cabot, the son of John. Sebastian, *en route*, lured by silver-tongued fable, diverted the expedition, sailed for and ascended the Plata estuary and river Paraná, and attempted the conquest of the Plata Valley. Disaster attended him, and with a single ship he returned to Spain. That valley is now being developed into a prosperous state by the application of 200,000,000*l.* sterling of European capital—three-fourths of which is British—and is already the home of five millions of thriving, intelligent, and energetic people.

Sebastian Cabot having been brought up as a boy in this city of Bristol, I have thought it not inappropriate to this occasion to give you some idea of the land which he tried to conquer, and how Nature has there marshalled her forces. She has, within easy reach, all the elements she requires for action upon the most imposing scale; and it must be admitted that she has brought them lavishly into play. The present drainage area of the Plata basin is, according to Dr. Bludau, 1,198,000 square miles, being over two and one-half times that of the entire Pacific slope of the Andes. The minimum water discharge into the Plata estuary would, every twenty-four hours, make a lake one mile square and 1,650 feet deep. About 74 per cent. of it would represent the flow of the Paraná, and 26 per cent. that of the Uruguay River. In my subject, the latter plays only a secondary part; the majestic Paraná and its branches assume the primary *rôle.* These interlace with the affluents of the Amazon along a line of 14 degrees of longitude. Even on the ocean I have been unable to realise vastness, as regards quantity of water, to the extent which I have while standing on the bluff overlooking the Paraná at Rosario, and also on the bank of the Amazon at Obydos. Dark, profound, and mysterious, the rivers ceaselessly roll past, ever in the same direction, never to return; and, awe-struck, one reflects that, for æons of ages, they have never halted in their stately march, and asks where and what is the power that gathers and lets loose these mighty floods?

Extent of the Plata Basin in Ancient Times.—I shall try to show that the Plata drainage area was, in a recent geological period, much more extensive than it is to-day; that its most northern limit was in 10° 44′ south latitude, and that nearly the entire waters which now unite to form the Madeira River, the main affluent of the Amazon, once flowed southward into a Pampean sea, which penetrated north, over the plains of the present Argentine Republic, to about 19° south latitude.

To elucidate this proposition, I must call attention to the topography of that great Bolivian basin across which the whole northern and eastern slope of the Bolivian Andes and the western slope of Brazilian Matto Grosso send their abundant drainage to the falls of the Madeira. The present elevation of the upper fall has been found by instrumental survey to be 547 feet above sea-level. The distinguished engineer, Julio Pinkas, who made the survey, estimated the drainage area of the Bolivian basin at 400,000 square miles. This is somewhat in excess of, but perhaps more accurate than, my own estimate, made when I descended the Mamoré River and the Amazon, in 1871. Elsewhere, I have shown that the Bolivian rivers lie upon a great plateau, high above the river Purús, as well as above the lower Madeira. The Andes form the south-western and western rim of this plateau, and, between the Mayu-tata and Purús, push low hills north-east towards the falls of the Madeira. On the eastern side are the Matto Grosso highlands, and, south-east, the low Chiquitos sierras of San Juan, the Sunsas, San Lorenzo, Ipias, Chochis and Santiago, some of them overlooking the Argentine Gran Chaco, and having a southern drainage into the river Paraguay. The grand rim of the Bolivian basin has two breaks; one leads to the Amazon Valley, by the falls of the Madeira, and the other, in longitude 62° west from Greenwich, and latitude 18° south, opens into what is now known as the Plata Basin. Further on, I will attempt to show how a dam was gradually thrown across this southern gap, until its elevation, once much inferior, became superior to that of the ancient lip of the falls over which the Bolivian rivers now plunge.

The mean flow of the Madeira River, at the moment of receiving its united Bolivian tributaries, is, according to Keller, 8,654 cubic mètres per second, equal to 305,616 cubic feet. Pinkas makes it 6,874 cubic mètres. These must be rough calculations; for the mean flow of a river of such variable conditions could only be accurately measured by a series of observations extending over several years. I believe it is equal to that of the Paraná and Uruguay at their junction.

Outline of the Basin.—The Matto Grosso highlands, overlooking the Bolivian basin, are composed almost wholly of red sandstone, overlying argillaceous schists; but, near the head waters of the Guaporé river, which skirts their western base, are found rose-coloured gneiss, talc schists, and sandstones, on which frequently rest large areas of a recent alluvium, locally called *canga*.

The Chiquitos sierras rise, on an average, from 1,400 to 2,000 feet above the sea. (Minchin mentions a peak 3,600 feet high.) I agree with Dr. J. W. Evans that, as described by D'Orbigny, they present evidences of belonging to the earlier Brazilian highlands, rather than the younger elevation of the Andes. The western section is a wall of friable, ferruginous sandstone, sometimes flat-topped, while the extension, towards the Paraguay River, is a compact sandstone overlying talc schist, which, towards the north-east, rests on gneiss in decomposition. The San Juan and Sunsas sierras are the most northern of the Chiquitos group. The former is mostly of gneissic formation, but the latter is of sandstone resting on talc schist.

The Bolivian Andes, which face the Amazon and the Gran Chaco, are almost entirely composed of feldspathic sandstones, micaceous and blue slates, clay and sandy shales, at times showing a thickness of from 10,000 to 15,000 feet. In riding from Cochabamba to Santa Cruz de la Sierra, I have especially noticed them exposed upon a gigantic scale.

The upper fall of the Madeira, called Guajará-mirim, runs over the ferruginous, conglomerate rock called *canga*. This rests on argillaceous sandstone, which crumbles easily by the action of running water. The *canga* gradually becomes undermined, and, breaking in pieces, is moved by the currents into deep water: thus the elevation of the fall is gradually lowered. Keller gives a notable example of such erosion, at a point called Matucaré, on the lower Madeira River. All the other barriers which form the falls are varieties of granitic and metamorphic rocks.

About eighteen miles above the mouth of the Beni branch of the Madeira, and below that of the Mayu-tata, is the fall of Esperanza, having a drop of 20 feet in a length of 1,000. According to M. V. Ballivian, the rock is of *canga*, the same as that of Guajará-mirim.

Pinkas found that, on the right bank of the upper Madeira River, several places are still visible where the erosive action of the waters has stripped the primitive rocks, anciently covered by a bed of ferruginous sandstone. I also saw evidences of the erosive action of the river, near the upper falls, and am disposed to believe that, in the lapse of centuries, one or two rapids, higher up the river, have disappeared; not, however, entirely, for a reef of ferruginous conglomerate still partly crosses the Mamoré River, between the mouth of the Guaporé and the town of Exaltacion. It is probable that the western Matto Grosso hills once extended westward to the Beni fall of Esperanza, where they met the Andean foot-hills, and added to the height of the barrier which prevented the river system of Bolivia from breaking through to the north-east. How high that barrier may have been it is difficult to determine, owing to the country being densely forested; but in the fork of the Beni and Mamoré I found hills perhaps 150 feet elevation above the river; and Keller mentions some on the left bank of the Beni near its mouth. The rocks of Matto Grosso are so soft as to offer but slight obstacle to the erosive power of the mighty flood of the Madeira; and, if we admit that the lip of its upper fall, when the river began to flow over it, was only 100 feet higher than now, it will be but a small allowance in comparison to the depths which even insignificant streams have excavated over the immense area of Matto Grosso. The falls of the Madeira appear to have completely cleared off and exposed the granitic and metamorphic rocks upon which the Matto Grosso shales and sandstones once rested.

Immense quantities of detritus have found their way down the Andes. The volume carried by the little river La Paz, the remotest branch of the Beni, is astounding. I once descended it to ride round the base of Mount Illimani. The river is so hemmed in between the material of the Titicaca basin and that monarch of the Andes that I had to ford it 108 times in one day. It has cut a profound gorge through the inland range perhaps 50 feet wide and 600 feet deep. The overhanging precipices looked not over 40 feet wide at the top. Through this dark rent, which I had to penetrate or turn back, the river swept me, horse and all, as if I had been launched from a catapult.

The bed of detritus and alluvium which the river skirts for about 50 miles is one of the most remarkable in the world. Forbes gives it a total thickness of 2,000 to 2,500 feet 'of alternating beds of grey, bluish and fawn-coloured clays, gravel and shingle beds, with boulders of clay slate, greywacké and granite, frequently of enormous size and well rounded, as if by the action of water.' In my ride down the valley I saw Nature at work tearing into this deposit, and sending it on its way to the great basin of the Beni and Mojos. During certain months, generally from November to March, a prolonged and violent local storm may arise in some lateral valley of the river. The waters then sweep impetuously down, taking with them hundreds of thousands of cubic yards of material, which they pile across the La Paz River. The mass of clay and boulders rapidly becomes cemented and compacted, and holds its place until the La Paz in turn, swollen by some storm from Illimani, bursts the huge dam and hurls its contents down the valley. I noticed boulders of many tons weight, at least 300 feet above the bed of the river, sticking, like half-exposed marbles, in the side of the perpendicular wall of detritus which towered even high above them.

Similar denudation is going on along the entire Andean slope. The great Rio Grande carries a prodigious mass of alluvium into the gap which lies between the extreme eastern counterfort of the Andes and the Chiquitos sierras. Even its little branch, the Piray, which I descended, desolates the country far and wide, in periods of flood, with trees, sand, and mud. The Rio Grande and the Parapiti must have transported to the plain, to the east of Santa Cruz de la Sierra, millions on millions of cubic yards of material, and have filled it to a depth of several hundred feet. The examples I have given from personal observation can, however, but faintly convey an idea of the grand scale upon which Nature is at work tearing down the Atlantic slope of the Bolivian Andes. So far, she has succeeded in only outlining the task she has assumed, for she appears to have finished nothing. The finer touches cannot be put on with such riotous vigour.

Later, I shall show how the closing of the southern gap caused the formation of a lake in the Bolivian Mojos basin, the lacustrine character of which is not yet eliminated; for, during a period of about four months of the year, some 35,000 square miles of its surface are covered with the surplus water which cannot find exit over the falls of the Madeira, they not yet having been worn down enough to give complete drainage to the basin; or else this is not yet sufficiently silted up to keep it out of water. Castlenau says that, 'Due to their horizontality, all the plains, from the mouth of the Mamoré to the Pilcomayo, are inundated from October to March, and present the aspect of a great ocean dotted with green islands;' and, speaking of the great southern gap, says: 'Across the Monte Grande, a simply overturned tree would change the course of the waters.' D'Orbigny is eloquent in his descriptions of the 'smooth surface' and 'unlimited horizon' of the vast plains of Mojos and the Beni.

Between Santa Cruz de la Sierra and the northern frontier of the Argentine Republic, the Pilcomayo River gathers its waters amidst masses of red sandstone and argillaceous schists. Further southward, the Andes are broken into a number of secondary ridges of palæozoic composition, among which are the sources of the Bermejo and Salado. In the most southern extension of these ridges we find limestones and compact sandstones, mica schist, gneiss, and granite. From about latitude 30° south the Andes lose their great width, and thence confine themselves to the Pacific coast ridge, as far south as the Straits of Magellan. According to De Moussy, 'the lower sierras, which lie to the east, present a great variety of stratified, crystalline rocks, saccharoids, slate schists, bituminous sandstone, basalts, obsidian, trachites, pumice, crystallised and amorphous quartz.'

The Sierra de Cordova, extending north and south for nearly 300 miles, and having a summit about 7,500 feet above ocean-level, was probably an ancient group of islands in the Pampean Sea. It consists of several parallel chains, composed principally of quartz, gneiss, and limestones of various colours. De Moussy found trachitic rocks on their northern extension, and evidences of volcanic action. South-west, and separated from the Sierra de Cordova, is the low San Luis range of gneiss and mica schist, and sometimes crystallised quartz. Vast masses of rounded shingle, covered by a thin cap of argillaceous earth and coarse granitic sand, border the valleys. The Alto Penasco sierra, forty miles west of the San Luis range, is also composed of crystalline rocks. The Cordon de Paramillos, near Mendoza, is of porphyry, sandstone, schists, and limestone. Here also, 'immense quantities of rounded and rolled shingle cover the base of all the chains and interior valleys. The torrents cut the accumulated *débris* to a profound depth, and expose its enormous thickness. The bottoms of the valleys are entirely composed of it.'

Penetrating north of Mendoza, we find white sandstone, and mountains of red sandstone and argillaceous conglomerate in full process of decomposition. These abound, above all, in the provinces of La Rioja and Catamarca.

Southern Extremity of the Basin.—From Cape Corrientes inland, ranges of hills, irregularly massed in line, extend north-west about 150 miles. They are known as the Sierra de Tandil, and are widest at Tandil. Their greatest elevation above the sea is 1,476 feet. My old friends Heusser and Claraz say the range is 'composed of sandstone caps resting on gneissic-granite, showing the Pampean formation in the valleys and on their slopes.' Sometimes the gneissic-granite shows bare, and at others elevated into sierras with slopes covered with Pampean formation.

Further south-west, and lying between the Tandil and Bahia Blanca, are the metamorphic sierras Pillahuinco, Ventana, and Curamalal, extending west and north-west, a total length of about 100 miles, nearly to Puan. In 1859 I spent a turbulent period of several months among these mountains, as a member of a commission charged to explore the south-western frontier of Buenos Ayres, which was then being raided by the Patagonian, Araucanian, and Pampa tribes of savages. Referring to my old field-book, I find evidences that some of my notes were made in a hurry.

The greatest bulk of the Ventana range appears to be gathered near the highest peak of the Curamalal section, the elevation of which, by trigonometric measurement, I found to be 3,363 feet above sea-level, and the Ventana peak 3,563 feet. The inclination of their strata is from 60° to 85°, dipping, with little variation, to the north-east. On their south-west slopes, so far as we explored them, these mountains are composed of extremely hard quartz rock, white, pink, and other colours. In many places it was cut into large rhomboidal-shaped solids.

The highly calcareous, argillaceous rock-cap of the plain which lies between the Ventana and Bahia Blanca slopes west-south-west, its elevation at the southern foot of the Ventana range being about 500 feet, and at Nueva Roma about 230 feet, above sea-level.

Scattered over the surface of this plateau are many hollows, which in some instances are 100 feet below the general level. At their bottoms small lagoons are frequently found.

On the *northern* slope of the culminating peak of the Ventana I found a conglomerate of rounded quartz pebbles, cemented by sandy, ferruginous matter. I have seen specimens of similar conglomerate from the north-west slope of the Curamalal range. I do not know the elevation of the bed which I found, but, for several reasons, believe it to be about 1,200 feet above sea-level. It was, in great part, cemented to the quartz rock of the mountain, although masses of it, cubic yards in volume, had broken down or become displaced. Darwin states that from 300 to 400 feet above the plain on the *south* side of the Ventana ('estimated at 840 feet elevation by some Spanish officers') he 'found a few small patches of conglomerate and breccia, firmly cemented by ferruginous matter to the abrupt and battered face of the quartz, traces being thus exhibited of ancient sea action.' He thus estimates the height of that which he found on the south side of the mountain at, approximately, the same as that which I found on the north side.

Explorers differ as to the character and structure of the great belt of dunes which stretches along the coast from Cape San Antonio to Bahia Blanca. I am familiar with them for a distance of only seventy miles east of the latter place, along which extension they are massed to their greatest breadth and height. Perhaps an unpublished leaf from my note-book of 1859 will enable you to realise what they are as I saw them:—'We proceeded to explore the course of the river Mostazas among the dunes. For seven miles we forced our horses over sand hills and through marshes and lagoons, although they sank to their knees at every step, and frequently floundered to their breasts in the burrows of the *Tuco-tucc*, the *Ctenomys magellanica*, about the size of a small rat. At last they lay down completely exhausted. Far to the east, we could still distinguish lagoons, but not a break in the coast line gave indication of the outlet of the river, while, all around us, the bare sand-hills reflected the sun with painful brilliancy. The exhausted condition of our horses obliged us to return dismounted. The dunes near the coast are composed of pure quartz sand of every colour, nearly all of it translucent. As they extend towards the interior, they have a slight mixture of earth, until their inland line is found to contain a preponderance of light, pulverised soil. Gradually a scanty vegetation appears, until, bordering the fertile lands, they are covered with coarse grass and a few stunted shrubs. Viewed from the north, they have an abrupt descent towards the west. Their coast line is about 110 feet high on an average, but inland they are of every elevation from 5 to 100 feet. The south-west gales violently agitate them, and cloud the air with their materials. Frequently, bowl-shaped excavations are found near their summits, which appear like works of art, so regularly are they scooped out by the wind, which must have been of terrific force. One of these, a detached hill of sand and dust, on the Sauce Grande River, about twelve miles from the coast, has had at least 5,000 cubic yards of material thus taken out near its top. At the bottom of the excavation I found several fragments of quartz rock, like that on the southern slopes of the Sierra Ventana. In all the dunes composed of pure sand I found, by digging four inches below their surface, on their sides or summits, that the sand was quite wet. Such was the case during our stay, although a very dry season. Numberless little lagoons, from 50 to 150 feet in diameter, with bottoms of soft mud, are scattered among them, around the margins of which grow rushes, weeds, and bunches of the exquisitely beautiful pampa-grass, the *Gynerium argentium.* Often, when the ponds were nearly dry, the soft, silky flowers of the pampa-grass had covered their muddy bottoms with a white mantle. Numerous aquatic birds are to be seen swimming in the shallow water of the open ones. Sporting with each other are *nutrias* (the South American otter, the *Myapotamus Coypus*), ducks, geese, black-necked swans, water-hens, and rose-coloured spoonbills, all so tame that I could sit on horseback within 20 feet of them without disturbing the amusements. I have counted fourteen otters in a small lagoon; and, from the apparent familiarity with which they rubbed noses with the ducks, they were as much a part of the family as any of the feathered tribe. I never molest them. It would be a pity to break in upon their Arcadia.'

I have lingered among the Ventana Mountains and in their vicinity, as they were once lofty islands which played an important *rôle* in arresting and protecting the Pampean mud.

Eastern Boundary of the Basin.—Cuyabá, at the head of the Paraguay River, is, according to numerous observations of Clauss, only 660 feet above sea-level. The valleys around it are bounded by vertical cliffs of red sandstone overlying argillaceous shales, which easily disintegrate. The Matto Grosso highlands, south of Cuyabá, as far as Paraguay, are practically unexplored; but I have no doubt they are of the same formation of sandstone and shales resting on metamorphic rock.

The Apa River, which is the northern boundary of Paraguay, drains a limestone district. Bourgade says 'the main framework of Paraguay is a dark-red sandstone, but basaltic formations may be seen in many parts. Immense areas are covered to a considerable depth by a fertile red earth representing the decomposition of the sandstone hills.'

From Asunçion, the capital of Paraguay, south-east to the Apipé rapids of the river Paraná, the Cordillera of Caa-guazu throws off a range of hills which overlook a great triangular space at the south-west corner of Paraguay, slightly elevated above the sea, and consisting of low, sandy ground and morasses, at times flooded by the Paraguay River. This district, united to that of the Ybará lagoon, in Northern Corrientes, was probably the delta of the Paraná when it emptied into the ancient Pampean sea. The river is charged with but little silt in comparison to its much smaller affluent, the Paraguay; but, in flood, it carries a volume of water, said to be ten times that of the latter stream, and its width, along the northern sandstone border of Corrientes, is from three to nine miles. The alluvium, from the immense area of Brazil which it drains, is arrested by the rapids, reefs and falls of its middle course, where it violently tears a deep channel through huge beds of red sandstone, to afterwards unite its yellowish waters with those of the muddy Paraguay.

Lying between the rivers Paraná and Uruguay is the Argentine Mesopotamia, the provinces of Corrientes and Entre Rios, covered with modern alluvium. The former is gently undulating, and is half drowned in lagoons, the largest being the famous Ybará. The south and south-western part of Entre Rios is composed extensively of argillaceous earth, and the whole State is traversed by ridges of low hills running nearly north and south, the main ones never exceeding an altitude of 650 feet above sea-level. The framework of the province is of sandstone, covered in some places by shell limestone, and sometimes by granular limestone. The north-eastern part is sandy, with numerous hillocks of siliceous gravel. The exposed sandstone, on the river Gualeguay, extends north almost to the Ybará lagoon. On the left bank of the river Paraná, just south of its junction with the Paraguay, is the town of Corrientes, built on a red sandstone bluff. The same stone shows for thirty miles down stream, where it disappears, and thence for 240 miles the banks, sometimes rising to a height of 80 feet, and then at Goya descending almost to the river-level, are composed of sandy clay; but near Bella Vista are masses of rolled pebbles. Near the boundary line of Corrientes and Entre Rios the banks of the Paraná are very low on both sides of the river, and continue so for nearly 100 miles; but thence, southward, for 150 miles, the left bank is margined as far as Diamante by a range of hills from 125 to 160 feet high, at times boldly escarped and presenting a fine geological section. From Diamante the hills trend inland south-east about fifty miles, as far as Victoria, and they probably formed the border of an ancient channel of the river Paraná.

From Santa Fé to the head of the Plata estuary, the right bank of the Paraná shows a precipitous bluff of reddish clay, varying from 25 to 65 feet above mean-river level. It is being gradually undermined, and tumbles in great blocks into the river to add to its volume of silt.

The Uruguay River flows, almost throughout its course, over a rocky bed, mostly of red sandstone, at times very coarse, and then again of extremely fine composition; but below La Cruz, in Corrientes, there is much limestone, albeit the sandstone still predominates. The Uruguay is, except in flood, a clear-water stream, and, even at its highest level, carries comparatively but little silt.

I have ridden over much of the Banda Oriental del Uruguay. The southern and western half lies from 150 to 300 feet above sea-level. Darwin is correct in saying: 'It has a gently undulatory surface with a basis of primary rocks, and is in most parts covered up with an unstratified mass, of no great thickness, of reddish Pampean mud.'

Secondary Rivers.—I refer again to the very important rivers Grande and Parapiti. Minchin says of them: 'The Rio Grande drains a considerable part of South-eastern Bolivia. It has its sources among the ranges bordering the table-land, and flows for some 400 miles through a deep, narrow gorge, and reaches the plains in latitude 18° 55′. Bending north, it then describes a semicircle, and finally runs north-west to join the Mamoré. In its course across the plains, and as far north as latitude 17° 30′, the river flows through a wide sandy bed, bounded by banks from 16 to 25 feet high. The Parapiti rises at an elevation of 2,030 feet in latitude 19° 59′ 18″, longitude 63° 4′. At the close of the dry season it flows 65 cubic yards per second, and is then absorbed by the sandy region of the plain. In the wet season it runs through a well-defined bed as far as latitude 19° 6′, longitude 62° 22′, and then spreads through the swampy, forest-covered plain. Its waters, again uniting, cut through the south range of Chiquitos at Qumome Pass and form Lake Concepçion.'

Between 20° and 30° south latitude the arid Andean slopes collect and send south-eastward, across the Gran Chaco, the waters of the three great rivers Pilcomayo, Bermejo, and Salado or Juramento. They are almost without an affluent once they leave the foot of the mountains, where they have their greatest volume. Sometimes they split into several channels, making narrow and enormous islands in the plain. They are all very crooked, and have uncertain beds, at times changing an old course for a new one miles distant. Thus they erode and tear away great quantities of soft Pampean material, dissolve it into silt, and pour it into the Paraguay and Paraná. Pelleschi, in his admirable work on the Gran Chaco, estimates that 'the soil annually subtracted from the territory of the Chaco by the Bermejo alone equals 6,400,000 cubic yards.'

The rivers Saladillo, Primero, and Segundo provide the water to meet the evaporation from the great inland lake of Porongos. The Tercero and Cuarto unite, and enter the Paraná near Rosario, with a considerable volume of water. The Quinto, with other small rivers, draining the southern spurs of the Cordova range, are absorbed by the thirsty Pampean swamp, La Amarga.

Some of these rivers carry a large quantity of lime, and many of their westerly affluents carry so much as to have a white colour, thus accounting for the considerable number of them called 'Rio Blanco.'

A large river system, having many ramifications in the provinces of La Rioja, Mendoza, and San Luis, gathers into lagoons and main channels to find its way to Lake Urre Lauquen, and, in floods, to the Colorado. Physical and climatic changes, of which I shall treat, have profoundly modified this section of the Argentine Republic, and reduced the volume of its waters.

I am indebted to several of the Argentine railway companies for sections of their lines, made from instrumental surveys. From these, and from other sources, including a carefully prepared table of altitudes by the Argentine engineer, A. Schneidewind, I have had plotted the sections which accompany this Address.

Sections of the Country.—Section 1 shows a part of the coast line of the Southern Railway. It is practically a cross section of the east coast of the province of Buenos Ayres from north to south, where the lowest part of the Pampean beds slope into the ocean. It passes also near the head of Samborombon Bay, which was once a great muddy estuary extending far inland, and the home of countless myriads of small crabs. The land slope of this bay so gradually merges into the ocean that, at a little distance, it is difficult to tell where the shore line meets the water. Century by century, it now slowly advances seaward.

Section 2, from Buenos Ayres to Rosario and Tucuman, shows with what regularity the country rises, from south-east to north-west, up to the outlying foothills of the Andes.

Section 3 is the first 350 kilomètres of the Neuquen extension of the Southern Railway, and shows in part the relation of the Colorado to the Rio Negro.

Section 4 is the Buenos Ayres and Pacific Railway to Villa Mercedes, and thence to Mendoza by the Argentine Great Western. Here we have a line almost on a parallel of latitude nearly to the frontier of Chile. Again we note the regular slope of the Pampa westward, until the country begins to swell into the Cordova sierra. Thence to Mendoza it is broken.

Section 5 shows the Bahia Blanca and North-Western Railway, as far as Toay, and thence its proposed extension to Villa Mercedes. It traverses a district the southern half of which has apparently been much troubled in former times by water, wind, and sand. From Victoria to Villa Mercedes the country assumes a more uniform slope, but beyond that, to the north, it rapidly rises into the barren mountainous districts of San Luis and Western Cordova.

Section 6 is the Central Argentine Railway, Rosario to Cordova. This is of interest as showing how far the uplifting of the Cordova range extended east, and nearly divided the Pampean Sea into a great northern and southern section. In fact, this railway is the southern border of a belt of rounded-up country, extending from the Cordova sierra to within thirty to forty miles of the river Paraná.

Section 7 is from Bahia Blanca north to Villa Maria (say 482 miles), thence to Cordova by the Central Argentine line, thence to Tucuman by the Central Northern section of the Cordova Central Railway, and thence to Jujuy by the Government Railway—a total length, nearly south to north, of, say, 1,127 miles. This section presents some notable features: between Bahia Blanca and Carhué it crosses the extreme western slope of the Curamalal sierra; thence to Villa Maria it shows an almost level stretch of Pampa, the lowest part of which, near Trenque Lauquen, is only about 300 feet above sea-level. This depression is on the parallel of Samborombon Bay, down to which it gradually slopes in a distance of 300 miles. From Villa Maria to Dean Funes the line ascends the Cordova Mountains, a marked feature of which is their bold western escarpment, overlooking the profound hollow which separates them from the south-eastern spur of the Catamarca sierras. In this depression lies the Salina Grande. From Tucuman to Jujuy, near the Bolivian frontier, the country rises rapidly towards that mountain bastion which is thrown so far east from the Pacific Ocean, and which is the true heart of the Andes. During a ride from Jujuy to Potosi I could not avoid being impressed with this mighty swelling up of the continent; and on several occasions, especially looking eastward, I was convinced that I could see the curvature of our globe.

Section 8 is the Buenos Ayres Western Railway. It stretches south-west across the heart of the true Pampean plain. The regularity of its gentle slope is remarkable.

Section 9 shows one of the lines of the Southern Railway, from Buenos Ayres to Bahia Blanca, and the gradual rise of the country south-westward, up the slope of the Curamalal Mountains.

Section 10. This is of great interest. It starts at the Atlantic coast, and is roughly parallel to and south-west and west of the Plata estuary and Paraná River, and from 70 to 100 miles distant from them, until reaching a point about 100 miles above the mouth of the river Pilcomayo; thence to the great gap, between the Bolivian Andes and the Chiquitos sierras, and thence to the lip of the first fall of the river Madeira—a total length of about 1,770 geographical miles (about 3,300 kilomètres). This line, from the great gap to the Atlantic coast, was approximately that of least resistance to the flow of the Pampean mud. I have called attention to the very gradual north-eastern swell due to the Cordova sierra. This section clearly shows it, and indicates, moreover, that the Salado, or Juramento, River flows along its lowest margin, and serves as the boundary of the most southern part of the Gran Chaco. In fact, the Salado occupies the south-west side of a very level depression, 300 miles across, and only 240 feet above the sea, along the north-eastern edge of which runs the Bermejo. The northern undefined limit of the Gran Chaco is probably the Chiquitos sierras. From the Bermejo, northward, the section shows the slope of this Chaco district. It is the natural incline which the waters gave it as the sand was poured in from the north.

I have been obliged to estimate the height of the present water-divide between the Plata Valley and the Mojos Basin. For the first 240 miles north of the divide I allow a slope of 9 inches to the geographical mile, and thence down the Mamoré River to the present lip of the Madeira Falls, a descent of about 4 inches to the mile. Like Keller, I found the Mamoré to be a very sluggish stream, 'the inclination very small.' Barometric measurements I could not take, owing to the failure of some instruments and the loss of others. The height of the upper fall of the Madeira is shown to be 547 feet above the sea. It has served as my starting-point in estimating the summit of the water-divide at 817 feet. Minchin gives a few widely separated barometric measurements on his map of the neighbouring country to the east, and I judge that he makes the divide perhaps 100 feet higher than I do. I should be glad if so able an engineer would give us further information about it.

Formation of the Bed of the Pampean Sea.—A vast area of the Plata Valley is covered, to a depth of from 20 to 100 feet, by a bed of reddish-yellow, semi-plastic, argillaceous earth, varying in colour, hardness, and constituent parts. It is mixed with a little sand, and has traces of titanic iron and olivine. Due probably to underground percolation from the lime-carrying rivers, it frequently merges into a marly rock full of calcareous nodules. This rock is found over immense areas of the country, and is at times apparently stratified. Great numbers of the Calomys Biscacha burrow in families under the rocky caps which are near the surface, and thus expose them to view. 'For this reason,' according to Heusser and Claraz, 'the Pampa Indians call the hard material "trui-cura," or Biscacha stone (*trui*, Biscacha; and *cura*, stone); but the country people have given it the name of *tosca*, of which the literal translation is tufa, whether it be the bed itself or the calcareous nodules contained in the clay. The Pampas are entirely without stones or pebbles. In general the Pampa clay becomes more and more sandy as one goes west. It is the same towards the south, starting from the Quejen Salado. There is much gypsum and carbonate of lime in the deposits, and much fine *débris* of a volcanic nature.'

In 1859, in a small cave excavated under a *tosca* cap at Nueva Roma, north-west of Bahia Blanca, I found stalactites from 6 to 12 inches long. Pelleschi tells me that at Puan, where a small stream has cut out a bowl-shaped depression (785 feet elevation above the sea by instrumental survey), there is a cap of *tosca* covering the district which is well filled with shells, closely cemented, but he does not know the species, and that on an island in a neighbouring lagoon excellent lime is made from a limestone rock found there.

A broad saddle of Pampean formation lies at an elevation of over 600 feet between the Ventana and Tandil Ranges. The *tosca* rock is almost everywhere *en évidence* in the sloping plain which surrounds the Ventana and Curamalal Ranges, and it is extensively exposed in the banks, and at the rapids and falls in all the little streams. I have noticed that, where these run over *tosca,* it has a hardened surface for a depth of perhaps half an inch. This is due to the hydraulic properties of the rock, which have in places been found so marked, notably at Rosario, in Santa Fé, that a few years ago, Carrasco states, the beds were worked for the manufacture of hydraulic cement.

D'Orbigny, Darwin, Bravard, Sir Woodbine Parish, Weddell, Heusser and Claraz, and others, disagree as to the origin of the 'Pampean mud.' Darwin wisely said 'it poured down from the north;' but the then paucity of geographical knowledge regarding the interior of South America did not enable him to fix its exact source and method of conveyance. Imbedded in the Pampean formation, over widely extended areas, have been found the fossil remains of the mastodon, megatherium, mylodon, and other gigantic animals, those from Rosario to the south being mixed with shells of species still living in the neighbouring seas. After the Pampean beds were formed, and their southern and eastern margin began to emerge from the waters, the ocean along the shallow coast rolled up on the gently-inclined plain quantities of shells, banks of which, miles in length, may be seen to-day far inland, giving evidences by their curvature and general appearance of having been piled up along an ancient coast line.

Not far from Bahia Blanca I have ridden for miles along the top of one of these embankments, about 20 feet high and 100 feet wide at the base. Most of the shells had been broken by wave action, and were mixed with abundance of rounded pumice, which probably floated down the Colorado and Negro from some volcanic centre of the distant Andes.

But a portion of the Pampean formation is still submerged, for *tosca* rock may be found throughout the length of the Plata estuary forming the bottom of its southern half. Thence it extends its eastern and southern margin, under water, along the coast of Buenos Ayres, at least as far as Bahia Blanca.

The *savants* whom I have named have presented us with abundant evidences that the whole Pampean formation was once submerged. What appears to have confused them is the finding of similar beds in widely-separated localities, and at elevations varying by thousands of feet. One may believe that, wherever in the immense drainage area of the ancient Plata basin the conditions of rivers, lakes, and inland seas were favourable to the distribution of silt from the mud-producing rocks which margin the entire basin in such prodigious quantities, there the 'mud' should be found; and it is conceivable that even to-day, if Nature were to form a lake by throwing a permanent dam across the entrance to an extensive valley leading into that basin, the streams entering it would there deposit Pampean mud. If this be true, there is no reason why such mud should not be found resting immediately on crystalline rocks in places. The extent of any continuous bed would alone be limited by the drainage area receiving the silt. The origin and age of a deposit wherever found, be it at sea-level or 12,000 feet above, or be it a square mile in area or 100,000 square miles, should be treated upon its individual merits. Darwin alone appears to have entertained doubts as to the contemporaneous origin of all materials similar to the Pampean beds, attributing their uniformity more to 'the similarity of the rocky framework of the continent.'

The Pampean Sea connected with the Atlantic Ocean between Uruguay and the Tandil Sierra. It was probably about 1,400 miles in length, with an average width of above 400 miles. Roughly estimated, its area must have been about 600,000 square miles—say about two-thirds the size of the Mediterranean Sea. The area of the ancient Mojos Lake was about 115,000 square miles, being seven-tenths that of the Black Sea, and exceeding that of the five 'Great Lakes' of North America, which is 93,581 square miles. The relation of the Pampean Sea to the Mojos Lake was similar to that of the Mediterranean to the Black Sea. Traces of it are still observable, notably the great, low, flooded morass of Xarayas on the Upper Paraguay River, and the ancient delta of the Paraná, including the Ybará lagoon. The Salina Grande was also an arm of it—a great inland fiord. The sea, moreover, must have covered large areas of Paraguay, Corrientes, Entre Rios, and Uruguay, and, before the uplifting of the country, it extended south-west to the rivers Chadi-Leofu and the Colorado, lapping round the southern slope of the Ventana Range until the curved rim, concave to the north-east, which connects this with the Sierra de Cordova, was sufficiently elevated to completely cut off its south-western extension. This rim, for the first fifty miles, starting at the Ventana, is about 700 to 750 feet above the sea, and shows much *tosca* rock near the surface. It afterwards rises rapidly towards the Cordova sierra.

The Uplifting of the Pampean Beds.—The Pampean beds were apparently laid down in shallow water. Their present irregularity and elevation may be attributed to pronounced local uplifting, followed by an extremely slow general upheaval of the Andes from west to east, which was communicated to the whole bed of the Pampean Sea, raising it ultimately to its present level. Gradually, as the Ventana, Tandil, and Cordova sierras were lifted, the mud settled upon their slopes until they ceased to exist as lofty islands, and with their connecting-rim of high ground formed a vast breakwater against any inroad of the ocean from the south or south-west. South of latitude 30° the force which raised the Andes has not shown the same vigour which it has to the north of that parallel, where it appears to have been greater in proportion to the broadening and swelling up of the mountain masses. As a resultant of this and its slope to the eastward, the northern section seems to be upheaved from the north-west, while, southward of latitude 30°, the real west to east action is apparent. Here the great distance of the Atlantic coast from the Andes has caused the eastern part of the province of Buenos Ayres to be raised but little, not sufficiently to lift the Pampean beds entirely out of the sea. In the north the gradually decreasing distance between the Cordillera and the Brazilian highlands confined the force and gave the plain its maximum lift at the great gap, at about 18° latitude, where the leverage of the Andes must then have ceased, due to the fact that at this point they take a sharp turn to the north-west, leaving the basin of the Beni and Mojos undisturbed.

This local and general upheaval determined the course of the Paraguay, the Lower Paraná, and the Plata Rivers, which were naturally pushed over against the more ancient Brazilian formation. It also, as the Pampean Sea retired, caused the Pilcomayo and Bermejo to take their south-east course across the Gran Chaco and find their present outlet.

The Cordova Range has lifted the Pampean mud to an elevation of about 1,300 feet above sea-level.

The Tandil Range has brought up, to a height of 900 feet, beds identical with the tertiary deposits 100 feet below the surface at Buenos Ayres. This indicates an upheaval of 1,000 feet since tertiary times.

Lying between the Bermejo River and the Salado, say the southern third of the Gran Chaco, we appear to have an almost undisturbed part of the bottom of the ancient sea—the present boundary belt between northern and southern climatic influences.

Age of the Pampean Formation.—The United States engineers, Humphreys and Abbot, estimate the amount of silt discharged yearly by the Mississippi River to be one cubic mile in twenty-two years. Although it carries, per cubic foot of water, much more silt than the Plata, I doubt if it exceeds that of the river Madeira, which now drains the Mojos basin, and is a very turbid stream.

The mean flow of the Mississippi at New Orleans is 675,000 cubic feet per second, but its maximum at flood is about 1,000,000. The minimum flow of the Plata, past Buenos Ayres, is 534,000, the maximum 2,145,000. It may, therefore, be fairly assumed that the yearly flow of the great North-American river is not superior, and may be inferior, to that of the Plata; and if it be admitted, as I believe, that the Madeira branch of the Amazon, at the falls, annually carries an amount of water equal to that passing Buenos Ayres, it will be evident that the total cubic volume of the streams which poured into the Pampean Sea must have been equal to twice that which the modern Mississippi contributes to the Gulf of Mexico.

Estimating the Pampean mud to cover an area of 400,000 square miles, with an average thickness of 50 feet, it would represent about 4,000 cubic miles of silt. The Andean and Brazilian shales and sandstones were probably disintegrated and dissolved with great rapidity when the rivers which tore them down flowed into the Pampean Sea. These streams must then have carried, one with another, a quantity of silt which, compared to that carried to-day by the Plata and Madeira Rivers, may safely be estimated at three-fourths the amount per cubic foot of water now carried by the Mississippi River. Allowing for partial loss of silt in the ocean, and from other causes, this would give the Pampean formation an age of about 70,000 years.

How the Ancient Mojos Lake was Formed.—I find the *divortium aquarum* between the Mojos and Plata basin to be only about 170 feet higher than the ancient lip of Guajará-mirim. It is easy to understand that the Rio Grande and the Parapiti have deposited there a quantity of alluvium far exceeding 170 feet in depth. The divide, prior to this and to the general uplifting movement described, could not have been more than 200 to 300 feet above sea-level, and thus much lower than even the present lip of the upper fall of the Madeira. Therefore, through this southern gap the combined streams which now form the principal affluent of the river Amazon found their way. Slowly the highly-charged, yellowish-brown waters sifted out and spread their heavier material over the sandy slope at the head of the Pampean Sea, leaving the fine silt in suspension to be precipitated over the submerged plains. The waters from the north were augmented in turn by the Paraguay and Paraná, the Pilcomayo, Bermejo, and Salado. From east and west numerous rivers pushed into the sea, stirring up its waters, and thus keeping the greater part of the silt in suspension to be carried far southward and deposited principally, and in maximum thickness, over the Pampean region south of latitude 30°.

The Grande and the Parapiti entered the plain with a northern trend to contest with the great river of the north the possession of the gap. They struck it almost at a right angle, and slowly pushed their rival eastward over against the Chaco base of the Chiquitos sierras. Here the final conflict must have taken place, as the Grande and Parapiti threw their dam across the outlet of the Mojos River, thus cutting off its exit into the ancient sea. No doubt the giant stream waged fierce war for thousands of years to keep its channel open, alternately sweeping away the barrier and again yielding to the ceaseless volume of sand and clay which, visible to-day, confirms the victory of the Grande and Parapiti. The dam having finally become permanent, the formation of the ancient Mojos Lake was assured (see physical map). When it reached the level of the lip of Guajará-mirim, its waters commenced to tumble over it and carve their way to the Amazon. Since then huge volumes of alluvium have poured down the northern slopes of the Bolivian Andes; the ancient lake is now almost loaded with material, but is not yet entirely obliterated. The muddy silt which covers the surface of the basin is so fine that, when an Indian goes up stream to the mountains, his friends ask him to bring back a stone that they may see what it is like.

Since forming the dam, the Rio Grande has slowly been returning westward down the counterslope which its own alluvium creates.

Slight Tidal Action of the Pampean Sea.—Off the mouth of the Rio de la Plata, the tides which flow south along the Brazilian coast meet those making north from the coast of Patagonia, counterbalance each other, and maintain the liquid mass at nearly the same level, so that the average tide at Montevideo is only about three feet. Thus the Plata River is able to pile its silt in a direct line further seaward than either the Orinoco or the Amazon. I have shown that the Ventana Range acted as a massive breakwater to the Pampean Sea, and that the Cordova sierra almost divided this into a northern and southern half. Hence the prevailing conditions appear to have permitted but little tidal action in the great basin. Had it been otherwise, as, *à priori*, one might suppose, the fierce contests which the tides would have waged when meeting the large rivers would have ripped up the Pampean beds and washed them into the ocean, and, in their place, we should now find nothing but a clayey, sandy, and shingle-covered waste.

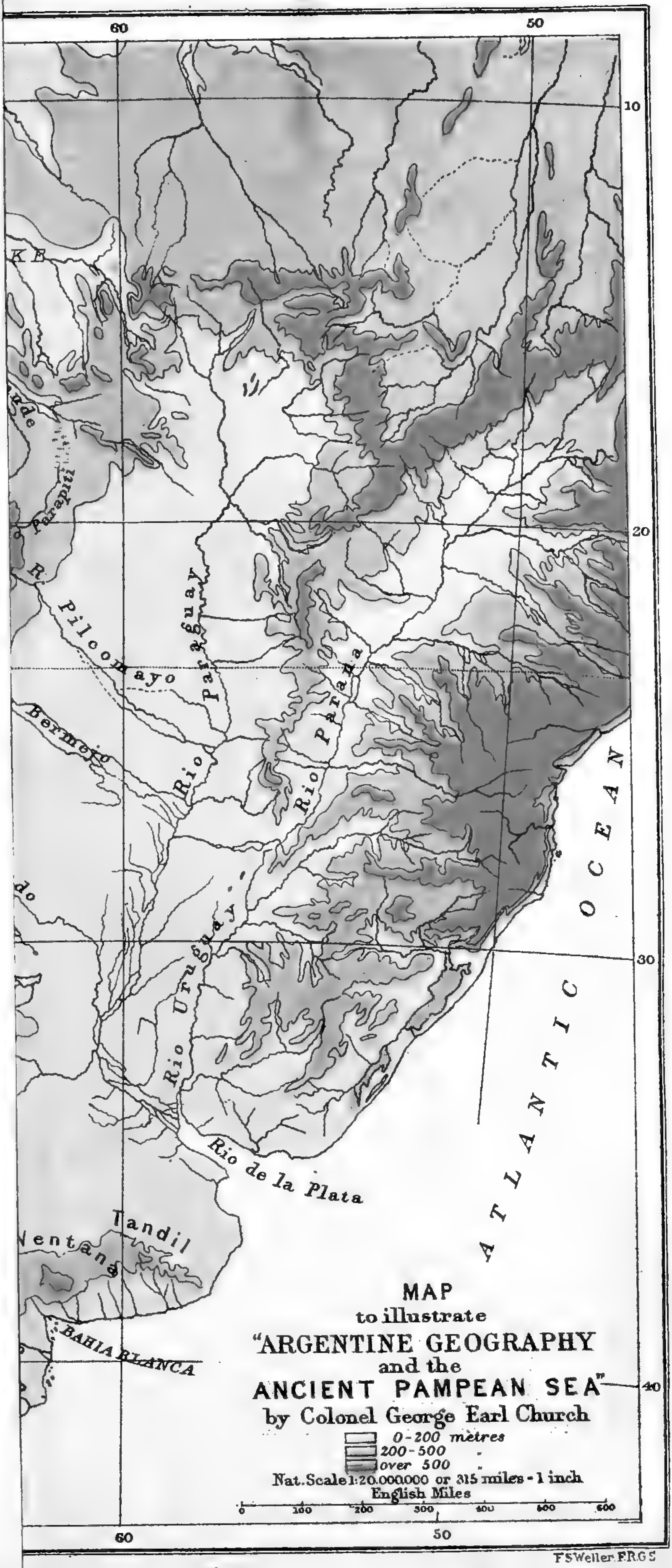
In 1860 I located the Northern Railway from Buenos Ayres to San Fernando.

An extremely violent 'Santa Rosa gale' swept up the Plata estuary. Finding by actual measurement that when its waters drove against the outflow of the Paraná River they tore 17 feet in one day into the high tosca bluff of San Isidro, I carried the definitive location over the hill instead of round the point at river-level.

The Inter-Andean Region.—The eastern inland Cordillera of the Andes which overlooks the Gran Chaco is separated from the Pacific coast range by a desert, bare and almost waterless belt of mountainous lands, from 250 to 300 miles wide, through the heart of which I have ridden. An extraordinary parallelism exists between the numerous lines of sierras, mostly running north and south, which fill the space. Between them are deep, scooped-out depressions, sometimes containing salt lagoons. In the rare occasions of violent storms, these receive torrential streams from channels which ordinarily carry but little water, and many of which are dry for most of the year. The whole district appears to be a southern prolongation of the Titicaca Basin, and possibly may have been so before the Andes reached their present elevation. As it extends southward it grows lower and less broken, and the *salinas* occupy a larger area until, to the west and north-west of the Sierra de Cordova, they are of enormous extent; but as latitude 30° is passed the eastern slope of the now narrow Andean chain begins to receive a sufficiently increased rainfall to supply the waters for the western system of Argentine rivers which try to find their way southward to the river Colorado, but which they only reach at rare intervals, when some exceptionally heavy storm aids their effort to satiate the sandy, thirsty desert which they traverse. This area of about 250,000 square miles (not a very comfortable country to march an army across) frequently presents evidences of marine action on a grand scale. D'Orbigny, Darwin, De Moussy, and Burmeister allude to the accumulations of rolled shingle found in the valleys and at the base of the mountains. Darwin speaks of the ocean as having 'long acted at the foot of the eastern Cordillera at nearly the same level as on the basin plains of Chile, and that the origin and transportal of these vast beds of pebbles is an interesting problem.' Perhaps a thorough study may show that the Patagonian gravel beds—76,000 square miles in area and 50 feet average thickness—were, like the Pampean deposits, in great part derived from the north. For reasons which I shall explain, I believe that all of this terribly eroded, inter-Andean district once had an abundant rainfall, and that, after the heavy material from the mountains had been sorted out, the rivers carried to the plains, to the west of the present province of Buenos Ayres, immense quantities of sand and clay derived from the masses of gneiss, schists, sandstone, and calcareous rock through which they flowed. For this reason, to the west of the curved boundary line of the Pampean beds, between the Ventana and Cordova sierras, the lands are dry, sandy, and uninviting.

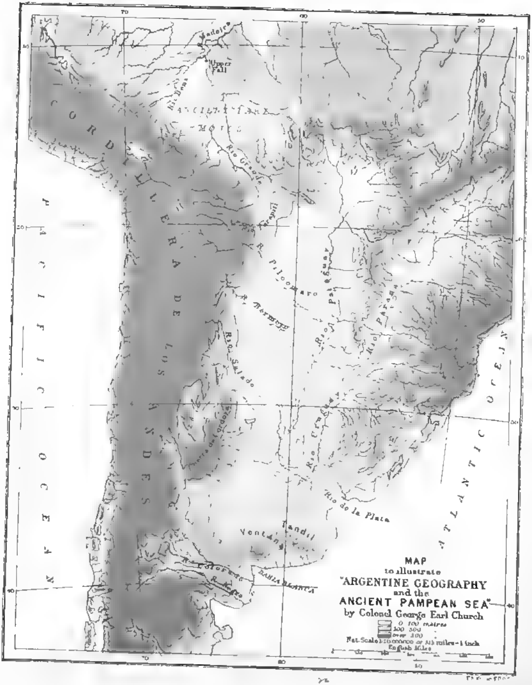
The contour lines of the country around the Lower Colorado appear to indicate that this river once emptied into a broad, shallow estuary, which penetrated inland from the present coast line about 116 miles. Over its bottom the Colorado dropped its silt, similar to the Pampean mud, but more siliceous. On what was once its northern shore, it is not surprising that Darwin should find 'an accumulation of high sand dunes, ranging westward from the coast twenty miles distant,' and which he believed 'were formed on the shores of an estuary.' It probably included the present Bahia Blanca and its coast line as far as Mount Hermoso, to the east of Punta Alta, where Darwin found so many fossil remains of gigantic mammifers. May we not suppose that these came from the north, were floated down the Colorado, and taken to this point by the northern currents which sweep along the Patagonian coast?

Climatic Influences.—It must be admitted that an ancient sea two-thirds the size of the Mediterranean, and a lake much larger than the total area of the 'Great Lakes' of North America, must have profoundly affected the climatic conditions of the adjoining regions. Perhaps no part of the world presented an example where the forces of Nature had an opportunity to display their power in equal magnitude, over such a continuous area, and with such uninterrupted simplicity. To the west, the Andes served as a lofty condenser, which, for a distance of over 2,500 miles, guided the cold polar currents towards the equator and



MAP
to illustrate
"ARGENTINE GEOGRAPHY
and the
ANCIENT PAMPEAN SEA"
by Colonel George Earl Church

F S Weller, F.R.G.S.



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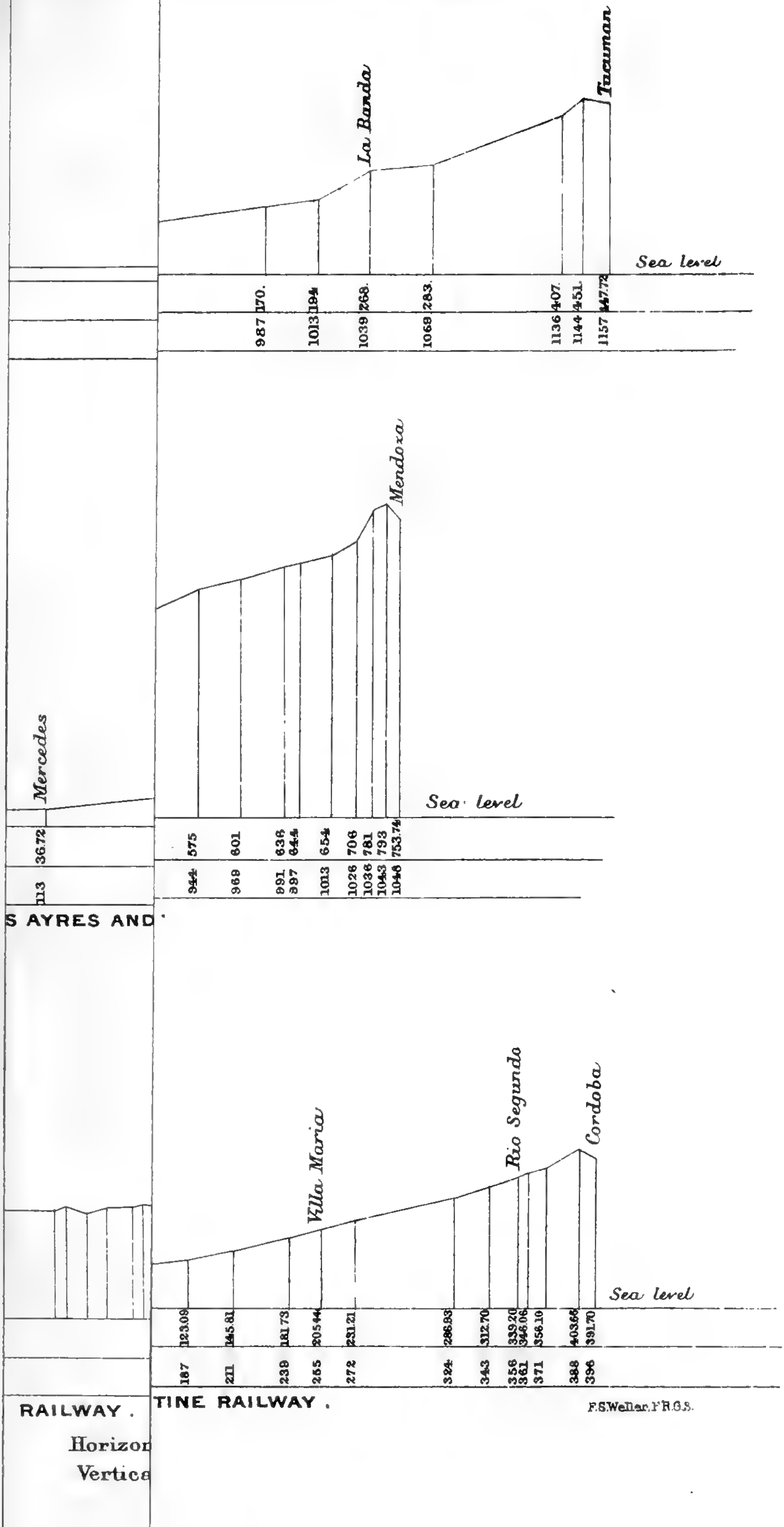
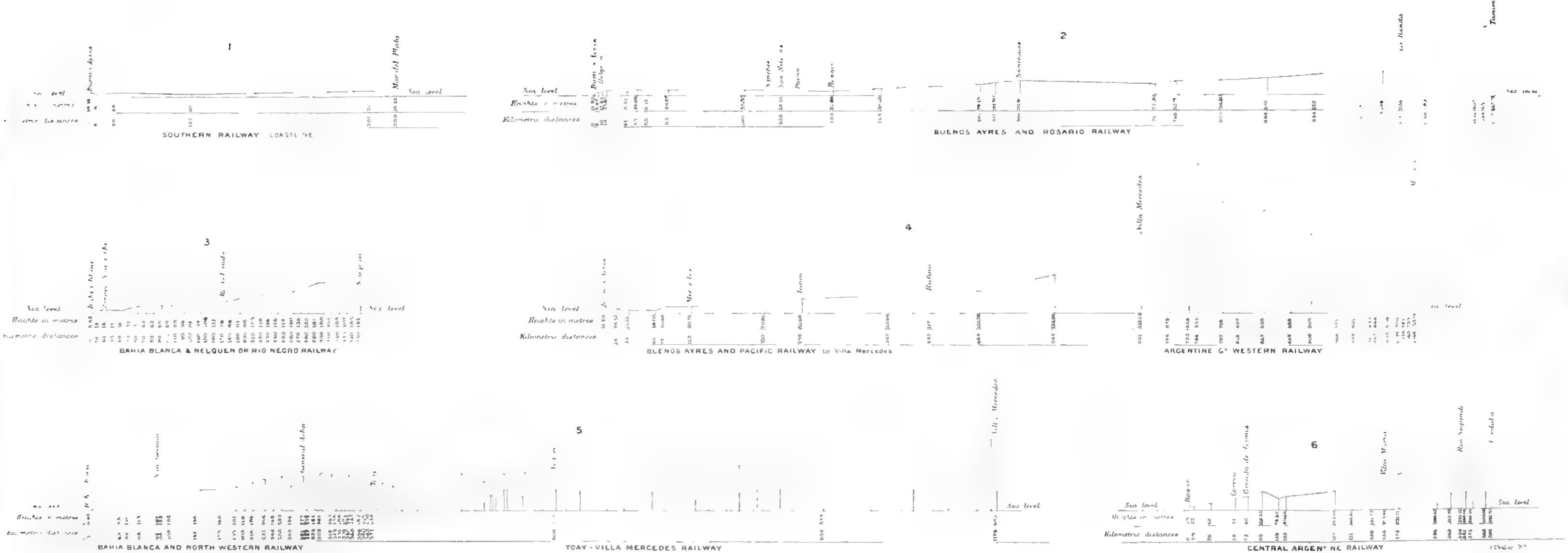

La Banda
Tucuman
Sea level
170.
194
268.
283.
407.
451.
447.72
987
1013
1039
1069
1136
1144
1157
Mendoza
Mercedes
Sea level
36.72
575
601
636
644
654
706
781
793
753.74
113
944
969
991
997
1013
1028
1036
1043
1048
S AYRES AND
Villa Maria
Rio Segundo
Cordoba
Sea level
123.09
145.81
181.73
205.44
231.21
286.83
312.70
339.20
346.06
356.10
403.68
391.70
187
211
239
255
272
324
343
356
361
371
388
396
RAILWAY.
TINE RAILWAY.
F.S.Weller, F.R.G.S.
Horizon
Vertica



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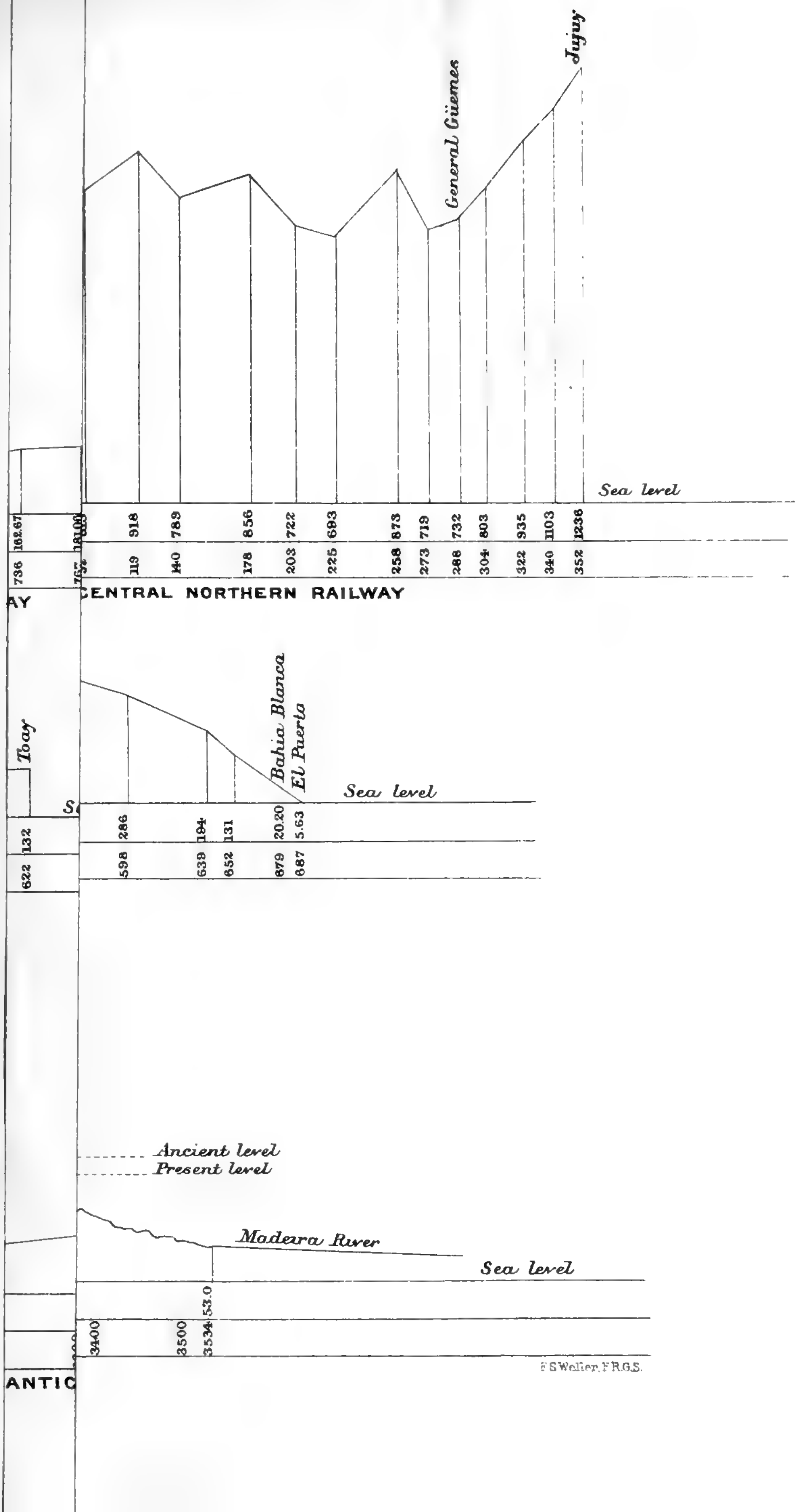
Jujuy
General Güemes
Sea level
182.67
181.00
918
789
856
722
693
873
719
732
803
935
1103
1236
736
757
119
140
178
203
225
258
273
288
304
322
340
352
AY
CENTRAL NORTHERN RAILWAY
Toay
Bahia Blanca
El Puerta
Sea level
132
286
194
131
20.20
5.63
622
598
639
652
879
887
Ancient level
Present level
Madeira River
Sea level
53.0
3400
3500
3534
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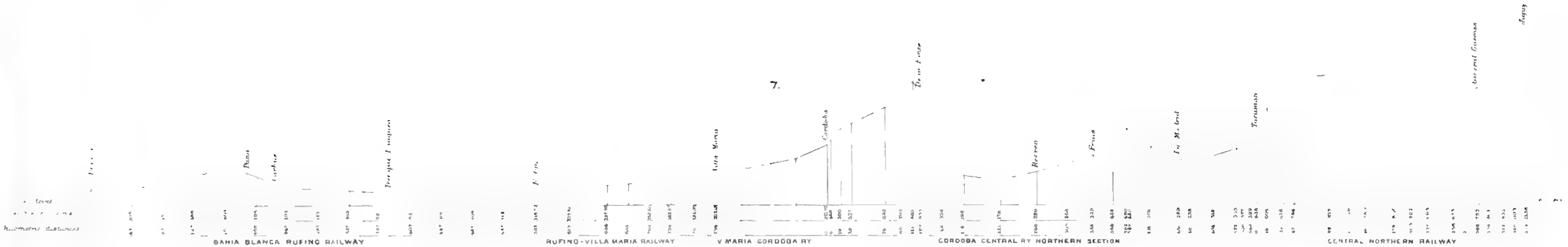
F.S.Weller, F.R.G.S.

7.



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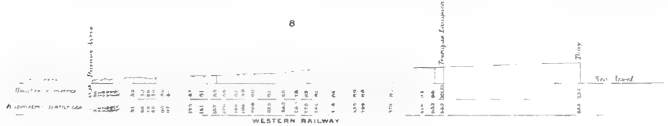
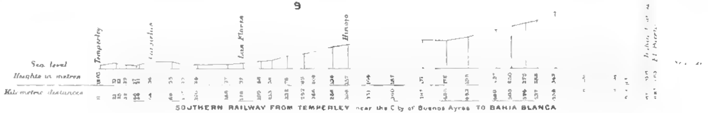


9



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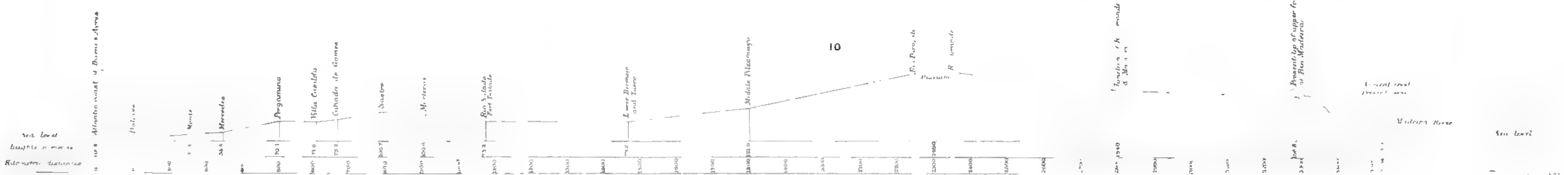
10



SECTION FROM THE ATLANTIC COAST OF BUENOS AYRES, TO THE FALLS OF THE RIVER MADEIRA.

Horizontal Scale 1 12 000
Vertical do 1 8 750 000

safeguarded their vigour. Similarly, the Brazilian highlands largely confined them to the great valley as they swept northward to do battle, in the heart of South America, with the warm vapours generated from the Pampean Sea and ancient lake, and the steaming, tropical basin of the Amazon. The extension of the vapour belt southward towards the Atlantic Ocean carried the equatorial currents nearer to the polar ones, thus inviting frequent atmospheric disturbance and resultant storm action. As the hot vapour-laden winds, fertile in elements of force, met the southern cold ones, a prodigious amount of heat was set free by condensation. Into the vacuum thus created the opposing currents rushed with ever-increasing rivalry, enlarging the area of mechanical action, condensation, and vacuum, and augmenting the violence of the storm-waters, which, sweeping along the mountain slopes, must have rapidly disintegrated and eroded them, and have acted as a potent agent to transport to their base much of the material from which the Pampean beds were sifted. The rainfall over the inter-Andean region must have produced many large lakes similar to Lake Titicaca, and a great river system, which, tributary to the Colorado, swelled it into a stream of the first rank, pouring into it the sand and silt which have completely filled the enormous estuary, the outline of which is still traceable.

One may believe that an increased rainfall gave a luxuriant vegetation, where herds of gigantic mammalia found feeding ground; from which, from time to time, they were swept, by storm or swollen river, into the Pampean Sea, where also they may have lost their lives in other ways, their remains being distributed over it by the currents.

To a minor degree the ancient sea and lake must have affected the inter-Andean climate, from Cuzco to the south, throughout the lacustrine basin of Titicaca, giving it greater rainfall and fertility than it now has. Geological examinations show that Titicaca was once one of the large lakes of the world, and that it has slowly been drying up. Does its gradual diminution date from the disappearance of the Pampean Sea and Mojos Lake?

Savage man may have lived in South America on the mountain slopes round the ancient sea. If so, he possibly hunted the mastodon, the megatherium, and numerous other of the gigantic fauna which probably were co-existent with him. His only highway, between the eastern and western halves of the continent, must have crossed the elevated region at the head of the Pampean Sea, lying between 17° and 19° south latitude, which is still the only route in use for communication by land between Bolivia and Matto Grosso.

The following Papers and Report were read:—

1. *On Waves.*[1] *By* VAUGHAN CORNISH, *M.Sc., F.R.G.S., F.C.S.*

The author is engaged upon an investigation of the phenomena of waves as far as they come within the scope of physical geography, and he exhibited to the Section a series of lantern slides illustrating various branches of the subject, including ocean waves, breakers, the tidal bore, ship waves, waves of rivers, the rippling of sand by wind, sand dunes, ripple mark and ripple drift, wave clouds, and rock waves.

2. *Report on the Climate of Tropical Africa.*

See Reports, p. 603.

3. *The Temperature and Salinity of the Surface Waters of the North Atlantic during the years* 1895–96. *By* H. N. DICKSON, *F.R.S.E.*

The author described the first results of a discussion of observations of surface temperature made in the North Atlantic during the two complete years 1895 and

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[1] The Paper will be published in the *Geographical Journal.*

1896 by the captains and officers of merchant ships. At the request of the author the captains of a number of the vessels also collected daily samples of surface water, and the densities of these, numbering about 5,000 in all, have been determined by chlorine titration. The material has been found sufficient to allow of the construction of charts showing the distribution of temperature and salinity over a large part of the area during each of the twenty-four consecutive months. The series, which is the first of its kind, shows the progressive changes in the manner of synoptic charts, and provides the data necessary for extending the work recently done in and around the North Sea, in connection with sea-fisheries and long-period weather forecasting. Specimens of the maps were shown on the screen.

4. *The Oceanographical Results of the Austro-Hungarian Deep-sea Expeditions* 1890–96.[1] *By* Dr. K. NATTERER.

The chemical investigations carried out by the author on board the vessels of the Austro-Hungarian deep-sea expeditions in the Eastern Mediterranean, Black Sea, and Red Sea took account of the dissolved oxygen, the chemical composition of the sea water, and the character of the deep-sea deposits. In places such as the neighbourhood of the Nile Delta, where the low salinity of the sea water keeps the same layer on the surface for a great length of time, and where diatoms are very abundant, the amount of dissolved oxygen was found to be greater than could have been absorbed from the air. Hence such portions of the sea replenish the oxygen supply of the atmosphere by the action of light on the marine vegetable organisms.

The nature of the deep-sea deposits was found to be largely dependent on the precipitation of carbonates and silicates, which are obtained by the solution of terrigenous deposits. Through the ammonia and carbonic acid produced by the slow oxidation of organic matter in the deep-sea ooze this precipitate often forms a continuous stony crust on the surface of the sea-bed, where its formation is not retarded by falling particles or remains of surface organisms.

In the Sea of Marmora solution, not sedimentation, is the rule, and this sea has peculiarly steep walls, subject to earthquakes, after one of which, in 1894, the depth was found to have been distinctly increased.

The author's study of the Red Sea and its bordering deserts leads him to believe that a very important part is played in rainless regions by the capillary ascent of sea water in the rocks bordering the sea, and that owing to the evaporation of the water thus drawn up are formed many of the salt and gypsum deposits found in the deserts.

FRIDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Theories on the Distribution of the Oceans and Continents.* *By* J. W. GREGORY, *D.Sc.*

The main object of geomorphology is to explain the existing distribution of land and water on the globe. A remarkable series of coincidences in the form and arrangement of the land masses suggests that the distribution has been determined by some general principle and not by local accidents. The three most striking features that require explanation are the antipodal position of oceans and continents, the triangular shape of the geographical units, and the excess of water in the southern hemisphere. Attempts to explain this arrangement have been made deductively from general physical considerations, as by Elie de Beaumont, Lowthian Green, and G. H. Darwin; and directly from the evidence of stratigraphical

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[1] The full Paper is published in the *Scottish Geographical Magazine.*

geology, as by Suess, Lapworth, and Michel-Levy. Thus Elie de Beaumont regarded the form of the continents as determined by the mountain chains, which he correlated into a regular geometrical network; while Lapworth regarded the distribution of land and water as due to a series of great earth-folds, the arches forming the continents, and the troughs forming the ocean basins. Suess has treated the subject synthetically; he has shown that the structure of the globe can be explained by subsidences in the crust when subterranean support is removed by the shrinkage of the internal nucleus, and by the movements of elevation which produce the chains of fold-mountains. Suess's view explains the structure of the continents and ocean basins, but not their arrangement. To settle this problem fuller knowledge is needed as to the distribution of land and water in past times. Neumayr's attempt to settle this question for the Jurassic was premature, and his conclusions are untenable. We are thus still dependent upon the deductive systems for suggestions as to the most profitable lines of research. Elie de Beaumont's famous scheme attached undue importance to linear symmetry and was too artificial. It led, however, to the tetrahedral theory of Lowthian Green, which regards the world, not as shaped like a simple tetrahedron, but as a spheroid slightly flattened on four faces. Such flattenings occur on hollow, spherical shells, when they are deformed by uniformly distributed external pressure. The oceans would occupy the four depressions thus produced, and the land masses occur at the angles and along the edges. The existing geographical arrangement is in general agreement with this scheme; for as the tetrahedron is hemihedral the assumption that the lithosphere is tetrahedral explains the antipodal position of land and water, the excess of water in the southern hemisphere, and the southward tapering of the land masses. The main lines of the existing system of fold-mountains have a general agreement with the arrangement of the edges of a tetrahedron. Some striking deviations occur, but are explicable by the variations in the composition of the lithosphere, and the existence of impassive blocks of old strata which have moulded the latter movements. The lines of the old fold-mountains of the Hercynian system may have been tetrahedrally arranged, with the axes occupying different positions from those of the great Cainozoic mountain system. So far, however, there is no completely satisfactory theory of geomorphology, for which we must wait for further information as to the distribution of land and water in successive epochs of the world's history. For the historical method promises more reliable results than the deductive method.

2. *The Great Indian Earthquake of June* 12, 1897. *By* R. D. OLDHAM.

The earthquake of June 12, 1897, in India was the largest and, with a few possible exceptions, the most violent of which there is any record. The area over which the shock was sensible was not less than 1,750,000 square miles, while the focus occupied an area of 200 miles in length and 50 miles in width.

Landslips on an unprecedented scale were produced in the Garo and Khasia Hills, and in the Himalayas north of Lower Assam. A number of lakes have been produced by changes of level due to the earth-movements by which the earthquake was caused, and the mountain peaks have been moved both vertically and horizontally. Monuments of solid stone and forest trees have been broken across by the violence of the shaking they have received. Communications of all kinds were interrupted; bridges were overthrown, displaced, and in some cases thrust bodily upwards to a height of as much as 20 feet, while the rails on the railways were twisted and bent. Earth fissures were formed over an area larger than the United Kingdom, and sand rents, from which sand and water were forced in solid streams to a height of 3 to 5 feet above the ground, were opened in incalculable numbers.

The loss of life was comparatively small, owing to the time of day at which the earthquake occurred—five o'clock in the afternoon—and the damage done was reduced by the fact that there are no large cities within the area of maximum violence; but in extent and capacity of destruction, as distinguished from destruction actually accomplished, this earthquake surpasses any of which there is historical record, not even excepting the great earthquake of Lisbon in 1755.

3. *On Earthquake Study.* *By* Professor J. Milne, *F.R.S.*

The author described the methods of seismological research now in use, and the progress that has been made in the establishment of seismometers in different parts of the world. The utility of these researches has been recognised by submarine cable companies as supplying a means of ascertaining the exact date of the fracture of cables by earthquakes, and in avoiding regions subject to earthquake disturbance when laying cables. The researches have also been of value to engineers in designing houses, bridges, and other structures to resist earthquake shocks.

4. *The Valley of the Yangtze.* *By* Mrs. Isabella L. Bishop, *F.R.G.S.*

The author recently travelled for eight months in the Yangtze Valley, making a journey of 1,200 miles by land in the Province of Sze-chuan, and nearly 2,000 by water, from Cheng-tu to Shanghai, during the land journey travelling up the smaller and western branch of the Min to its source at an altitude of nearly 1,100 feet, near the Tsu-kuh-shan Pass. In the opening of the paper she briefly traced the course of the Yangtze from the sea near Shanghai to its source on the confines of the Tibetan Steppes, pointing out the magnitude and utility of the affluents which it receives after its entrance into Sze-chuan, and the access given by these waterways into the very centre of the interior. Taking the Yangtze Valley in its full geographical sense, the region watered by the Great River and its affluents, as extending westwards for about 3,000 miles, and into the very heart of Asia, Mrs. Bishop pointed out that this region must be taken as including the Provinces of Kiangsu, Anhui, Hupeh, Honan, Hunan, Kwei-chow, Kiangsi, Ganhuy, Sze-chuan, Chekiang, and parts of Yunnan, Kansuh, and Shensi, making altogether the most accessible, the richest, and the most productive portion of the Empire, with an industrious and thrifty population of from 150,000,000 to 180,000,000. After briefly alluding to the treaty ports and the great cities of the Lower Yangtze, she entered more into detail regarding the country above Ichang, the head of steam navigation, and specially as to Sze-chuan, which, in virtue of its area, population, and resources, she considers the Empire Province of China. She described briefly the industries of the province, its superb climate, its vast wealth in coal and iron, its elaborately organised civilisation and modes of communication, the increase in the growth and export of opium, and in the import of Indian yarn for home weaving, and expressed the opinion that the increasing scarcity of *cash,* the fall in the purchasing power of silver, the *likin,* and the neglect of our manufacturers to study the needs of the Chinese as to the width, weight, texture, and patterns of cotton cloth, limit and hamper trade far more than the lack of steam communication on the Upper Yangtze. She noticed the genius for combination which exists among the Chinese, and stated that in Sze-chuan, with its population estimated at from fifty to seventy millions, every occupation has its guild, except trackers and water-carriers. While recognising the fact that this province is over-populated, she considers that it has an enormous amount of wealth and prosperity, and gave, among other indications of the former, the numerous fine country mansions of a leisured class, the size and architecture of the farm-houses, the handsome bridges and fine roads presented by rich men to their localities, the splendid halls erected by the guilds, the new temples, and the magnificent charities which are liberally supported in every city. Ignorance and superstition prevail, but she believes that the hostility shown to foreigners, who from having been 'Sons of the Ocean' a few years ago, are now 'Foreign Devils,' 'Child Eaters,' and worse, is instigated and fomented by the official class for easily guessed purposes of their own. She gave her own impressions of the Chinese peasantry of the Yangtze Valley, and concluded by reminding the audience that this 'sphere of influence' or 'interest' extends over a third of China.

5. *Across the Sierra Madre from Mazatlan to Durango.*
By O. H. Howarth.

The journey now to be described was undertaken in April of the present year, over a trail which, so far as the author is aware, has not previously been described by any European. It crosses the main range of Western Mexico on a line about 120 miles south of that followed by him in 1892, and referred to in a paper communicated to the Geographical Society in 1893. The recent erection of a direct telegraph line connecting the port of Mazatlan with the city of Durango led to the exploration of this new trail, it having been otherwise impracticable for any purpose except the casual mule traffic of the natives. The line runs in a north-easterly direction from the Pacific coast between the 23rd and 24th parallels N. lat., traversing an exceedingly wild and rugged district of the main range for a distance of 130 miles in a direct line, but nearer 200 miles following the precipitous contour of the mountains. There is probably no route through the great western range of North America exhibiting such vast alternations of elevation and depression within so comparatively limited an area. From Mazatlan the route followed was by a waggon road to the village of Presidio or Villa Union (alt. 120 feet), and thence to Concordia (alt. 380 feet), Piedra Blanca (610 feet), and the little mining town of Copala (1,750 feet), which was reached on the evening of Easter Sunday. Up to this point the ascent is generally an even gradient amongst the foothills for the first 30 miles or thereabouts; but for some 70 to 80 miles further the range is constantly broken by enormous chasms which the trail traverses by repeated zigzag ascents and descents, frequently of 1,500 to 2,000 feet within a horizontal distance of 2 or 3 miles. Between the ranche of Ocotes and the cañon of the Rio Valuarte a descent of 1,750 feet was made in a couple of hours; and on the afternoon of the same day the party camped at a point 4,600 feet above this, on the first 'Cumbre' or dividing ridge. Early the next morning the pass of Los Monos was entered at an elevation of 6,850 feet; and after descending again 2,000 feet to the Llanito (little plain) of Chavarria, another ridge of the Cumbre was crossed the same day at 9,600 feet altitude. Throughout this region, remarkable for the grandeur of its scenery, the main ridge of the western anticline, averaging 10,000 to 11,000 feet, seems to be split up into three or four parallel ranges with the above-mentioned deep gorges separating them. Beyond these commences a gradual descent from one to another of the curious mountain plateaus or 'Llanos,' including those of Las Juntas, Florida, Rusia, Mesa de Madroño, Coyotes, and Llano Grande, at altitudes from 9,100 down to 8,400 feet. These are usually open levels free from forest growth, and are utilised as grazing ground for cattle. Occasionally, on the higher of them, where a water parting occurs, may be seen a continuous stream course intersecting a plain not over a mile or so in length, at the ends of which the water is flowing in opposite directions. Beyond the Llano Grande extends a vast 'mesa' or tableland covered with scattered pine and other trees for a distance of some 30 to 40 miles at an altitude of 8,000 feet. As this approaches the last hill range overlooking the great plain of Durango the ground becomes open and clear of timber, forming to all appearance an uninterrupted sweep towards the brow of the range. Yet within a mile of this last descent the traveller finds himself suddenly on the brink of the tremendous gorge of the Rio Chico—a winding rift across the level which has to be descended to a depth of nearly 2,000 feet. Its geological structure is of great interest, exposing about half-way down a massive stream of pale grey vitreous lava, which has been covered to a depth of several hundred feet by other formations and sedimentary detritus. On reascending the opposite face and proceeding to the edge of the range the plain of Durango comes in view, with the city a few miles from the foot of the last descent. This was reached on the evening of the seventh day from Mazatlan. The observations as to physical structure, temperatures, vegetation, and especially the human and animal occupants of these remote mountain fastnesses were of more than ordinary interest, presenting several features distinct from those noticed in other parts of the Western Sierras.

SATURDAY, SEPTEMBER 10.

This Section did not meet.

MONDAY, SEPTEMBER 12.

The following Papers were read:—

1. *Political Geography. By* J. SCOTT KELTIE, *LL.D., Sec. R.G.S.*

Geography, like most other departments of science, is capable of practical applications to human affairs, and the application of the data of physical geography and anthropogeography to Communities, States, or Nations is Political Geography.

Physical conditions, such as position on the Earth's surface, determining seasons and climate, the surface characteristics of a region, such as its orography and hydrography, and the dimensions of the territory, all have direct bearings on the State. The question of boundaries and their definition is of vital importance in this respect, the natural limit of a neutral zone of desert, or at least waste land between two nations, gave way to the defined frontier, as often as not an arbitrary line not coincident with any natural feature, and of a validity depending on the general acceptation of the treaties by which it is defined.

The utilisation of natural resources and the amelioration of routes by land or water do much to develop a country, and bring out the real relation between land and people, which is the direct subject of political geography. The internal conditions of a country are to some extent responsible even for the forms of its government and its relations with other States. These are expressed peacefully mainly by international commerce, which takes place in spite of barriers both natural—such as seas, deserts, mountains—and artificial—such as Customs tariffs.

Internal development leads in certain circumstances to colonial expansion, and the relations of colonies to the mother country varies in accordance with the character of land and people. The rapid acquisition of foreign territory in recent years has given rise to certain new features of political geography—the sphere of influence, the leased territory, and the military occupation being the more important of these.

2. *The Prospects of Antarctic Research. By* HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

The problem of Antarctic exploration has varied in the course of the centuries from the purely theoretical discussion of the possibility of antipodes, to the search for a vast Austral continent of value to colonists and commerce. Since the voyage of Cook confined the limits of Antarctica to the south frigid zone, and the efforts of the few whalers and sealers of the early part of the present century proved that it could not rival the Arctic regions as a hunting-ground, the problem has become purely a scientific one.

As a field for scientific research the Antarctic has been kept before the public by Dr. Neumayer, of Hamburg, for thirty years, and in recent years Sir John Murray and Sir Clements Markham have been indefatigable in pressing upon successive Governments the claims of this region for a national expedition. The Royal Society, the Royal Geographical Society, and the British Association have given their powerful interest to the movement, but in vain.

The immediate prospects of research are more favourable than the action of Government might imply. A small Belgian expedition with a band of scientific enthusiasts is now in the field, and Sir George Newnes has sent out the *Southern Cross* with Mr. Borchgrevink to make an attempt to traverse the ice-cap from Cape Adare. The results of this expedition may be valuable, but they can only be viewed as preliminary. A German Committee has completed arrangements for sending out a finely-equipped expedition under Dr. Erich von Drygalski in 1900, and the Royal Geographical Society has headed a subscription list for a British expedition with 5,000*l.* It is urgently important that the great expeditions now being organised should not be in any sense rival projects; but that they should work in harmony, so as to make the greatest possible number of simultaneous and comparable observations on such important and little-known phenomena as the meteorology and magnetic conditions of the south polar area. The preliminary results of the expeditions already at work will probably arrive in time to enable the plans of the larger enterprises to be laid with greater certainty than our present knowledge of the region will allow.

3. *The National Photographic Record.* *By* Sir BENJAMIN STONE, *M.P.*

4. *Sokotra.* *By* Mrs. THEODORE BENT.

The name of the Island of Sokotra is probably a remnant of its old name, Diu Sukutera, corrupted by the Greeks into Dioscorides. It may, as Marriette Bey suggested, represent To Nuter of the Egyptian monuments.

Though geographically African, it is politically Arabian, having from far back ages been under the rule of the Mahri Sultan, as it is now.

The principal language spoken is called Sokoterioti. Mahri, or Mehri, and Arabic are also spoken, and many words of these languages are mingled in Sokoterioti, chiefly the former. The language is very polysyllabic.

The chief mountain range is Haghier, a high-shouldered, many-peaked mass. The highest point is Jebel Bit Molek, at 4,900 feet. All but the highest needles are densely covered with vegetation, where the civet cat is the largest wild beast, unless the wild ass may be considered such.

The north of the island has many khors, or inlets, where the sea runs in a mile or more, and also many lagoons fringed with palms and mangrove, separated by sandy bars from the sea.

The rivers on the north reach the lagoons, those on the south lose themselves in the sandy plain of Noget. In many places the mountains run out to the sea. There are many streams in the mountains, but little water in the E., W., and particularly S.W. parts of the island.

Inland large flocks and herds are tended by Bedouin living in little oval houses or mountain caves, according to the season. Pasture is very plentiful. The coast villages are inhabited by mongrel races, who export ghee and sharks' fins, but little of the myrrhs, gums, aloes, or dragon's blood once so famous. There is little cultivation of gourds, jowari, and tobacco, but tea and coffee might possibly grow.

Natural vegetation assumes strange forms, as adeniums and cucumber trees, with swollen trunk, dragon's blood trees, euphorbias, &c. There were an enormous variety of non-marine molluscs. The inhabitants are peaceable and honest. We saw no traces of Christianity but a few inscribed crosses, none whatever of Greek occupation, and little of Portuguese.

5. *The Upper Nile.* *By* Sir CHARLES W. WILSON, *R.E.*, *K.C.B.*, *F.R.S.*

6. *Twenty-eight Years in Central Australia.* *By* LOUIS DE ROUGEMONT.

TUESDAY, SEPTEMBER 13.

The following Papers were read :—

1. *Tirah.* *By* COLONEL SIR THOMAS HOLDICH, *R.E.*[1]

How the kingdom of Afghanistan came into existence. Its unstable nature and want of national vitality. The mixed elements of which it is composed. Its position as a buffer State, and the new creation of a buffer province between Afghanistan and India.

The demarcation of the boundaries of this province and the results. The reason for the late risings on the frontier as given by the people themselves. Geographical results. Up till the year 1897 we had a better knowledge of Afghanistan, Baluchistan, and Persia than we had of our own border.

The province of Roh and the Rohillas. Its position as a natural barrier to North-western India. The gateways through it, by which invasions have been conducted and the conquest of India from time to time effected. Position of Tirah in this new province of Roh. Geographical description. Nature of the roads leading into Tirah and reason for adopting the shortest line. Difficulty of passes. Description of Chagru Pass and Khanki Valley; of Sanpagha Pass and Mashura Valley; of Arhanga Pass and Maidán. The richness of its soil and formation of the cultivated slopes. Terraces and houses. Population and probable fighting strength of the tribe. Conclusion—future possibilities.

2. *Christmas Island.* *By* C. W. ANDREWS.

The author gave a short account of Christmas Island, Indian Ocean, where he stayed the greater part of a year. It is a raised coral atoll, which during its elevation has been surrounded by a series of reefs, so that now it presents the appearance of a flat-topped island, the coast of which is formed by a succession of step-like cliffs. The whole is covered by dense forest and jungle, which renders exploration difficult. The fauna and flora are specially interesting, on account of the isolation of the place. The most conspicuous animals are rats, land crabs, and frigate birds, the two latter forming the chief articles of food. There is also a wild sago palm, which is valuable for the same purpose.

3. *Notes on a Visit to North-Eastern Kamchatka.*
By Captain G. E. H. BARRETT-HAMILTON.

The north-east of Kamchatka is as yet only imperfectly surveyed, much of the coast-line being still represented by a dotted line on the Admiralty charts. It is very rarely visited; hence the observations made and the photographs taken during the cruise of H.M.S. *Linnet* off the coast, in August, 1897, possess some interest. They chiefly concern the island of Karaginski, situated in 59° N. and 164° E., about twenty miles off shore, and the neighbouring village of Karaga on the mainland. The mountains of this region do not probably exceed 4,000 feet in height, and in August still showed patches of snow. The village of Karaga contains seventeen balagans, or wooden huts, raised on piles to a height of about 10 feet from the ground, and six yurts, or wooden huts covered over with turf. The population of the village probably does not exceed thirty. The people were found to be very friendly, remarkably polite, and able to converse in Russian. Mosquitoes were a plague, and the natives wear skin gloves as a protection. Dug-out canoes are in use on the mainland, but only skin boats on the island. The islanders appeared to be very few in number, and exceedingly primitive and quaint in their ways. They dressed almost exclusively in home-made skin clothing; the nether garments,

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[1] The Paper will appear in the *Scottish Geographical Magazine.*

as on the mainland, were boots and breeches in one. They keep reindeer and sledge-dogs.

The paper was illustrated by a series of lantern-slides from photographs taken during the visit.

4. *The Impending Economic Revolution in China.* *By* G. G. CHISHOLM.

5. *On a Proposed Great Globe.* *By* Professor ELISÉE RECLUS.[1]

The author advocated the construction of a terrestrial globe on the scale of 1 : 500000—*i.e.* about 84 feet in diameter, the surface of which should show the relief of the Earth's surface on the same scale. He dwelt upon the educational and scientific value of a globe constructed in this way.

6. *The Edinburgh Outlook Tower.* *By* Professor PATRICK GEDDES.

The intellectual tradition of Edinburgh is not only one of education but of publication, and this not only of abstract philosophy, but also very largely of concrete encyclopædias,[2] and notably also of atlases, maps, and gazetteers. An ancient metropolis of national life and government, it remains a centre of historic interest and tourist resort. Unusually rich and complete in all the elements of a Regional Survey, it is also interested in world survey;[3] and if politically less important in the practical world than of old, it has become more widely connected with the world than ever—witness the proverbially wide dispersion of Scotsmen through England and the Empire, through America, and indeed through the whole world. Its great names are thus truly representative—Scott or Stevenson of the historic and romantic interest of their geographic microcosm; Adam Smith and his canny following of the economic shrewdness and foresight of a race disciplined by northern winters. These characteristic special interests and practical activities are thus really, alike in region and race, in unison; and the problem of the Outlook Tower is to express these, to give them objective expression, as the many sides of a single regional and racial development, in short as a geographic unity. This Regional Outlook Tower is thus itself a regional product; although its principle is easily adaptable to every region, as that of an encyclopædia may be used anywhere.

I. The Tower, therefore, in the first place, has arisen from the attempt again to prepare an encyclopædia, but now in *rational* order, exhibiting things in their mutual relations. Things are not mainly in printed, but in graphic form, and in rational order—*i.e.* with all subjects shown as far as possible in their mutual relations. Its basement rooms are thus planned first for an outline classification of the arts and sciences; of course not losing the traditions from Aristotle or Bacon to Comte and Spencer, but attempting a simple restatement of these. So far, however, its appeal is primarily to students of the special arts and sciences on the one hand; to the professed scientific philosopher on the other. To a more concrete treatment, however, and now one of direct appeal to the geographer, all the remaining storeys are devoted; the familiar rival methods of approach—(*a*) the narrowing from World through Europe, Empire to Scotland, City and actual Prospect and Neighbourhood; and (*b*) the starting with the most intimate detail of these and widening outwards to the World—being reconciled and equally utilised by the simple device of devoting one storey of the Tower to each of these areas. Thus the exhibition of the ground-floor centres round a globe with an outline survey of the main concepts of World-geography—*e.g.* an incipient collection of maps and illustrative landscapes, an outline of the progress of geographical discovery and of map-making, &c. The first floor is devoted to the geography and history of Europe in correspondingly fuller treatment; the second is set apart for

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[1] The Paper will appear in the *Scottish Geographical Magazine.*

[2] *E.g. Encyc. Brit.*, *Chambers's Encyc.*, &c.

[3] *Cf.* the Royal Scottish Geographical Society or the *Challenger* Expedition.

an outline geography and history of the English-speaking world, the United States having a room on the same level as the British Empire. On the third storey is preparing a corresponding survey of Scotland, viewed at once as an historic and social entity and as an element of greater nationality; while the fourth storey, naturally as yet in the most advanced state of preparation, is a museum of Edinburgh, though again not without comparison with Scottish and other cities. The flat roof of *Prospect* bears a turret of culminating outlook with a *Camera Obscura*, an old-fashioned instrument, but of great educational future, geographic and artistic alike.

Descending from the roof to the uppermost storey, this succession and unity of the physical, organic, and social conditions is better understood. Thus the relief model of the site of Edinburgh brings indispensable light on the interpretation of the antique and the modern city, its military history or its industrial present, its medical eminence or its picturesque interest.

Similarly for the storeys of Empire and Language, Europe, or World. On each level the view of Nature as determining man is complemented by that of man as more or less re-determining Nature.

The educational uses, whether to passing tourist or professed teacher, of such a Geographical School and Exhibition have already been proved in the Regional Studies which have for many years characterised the Edinburgh Summer Meeting. To the Great Globe projected by M. Elisée Reclus, wherever erected, such a Regional Tower is the necessary complement, its regional relief maps on greater scale, &c., furnishing, as it were, the corresponding regional *microscope*, bringing out the portions of the globe most interesting at that particular centre with clearer light and fuller detail.

II. Finally, the Tower has not only a scientific but a practical aspect; it is not only a Geographic Exhibition, but a Geotechnic Laboratory. On the level of the City are thus to be found not only the photographic survey of Edinburgh, but the plans and business detail of that repair or renewal of large portions of the historic city which has now been for many years in progress. The interests alike of archæology and public health, of æsthetics and finance, of the housing of the people, and of the collegiate beginnings for the academic community are here, so far as may be, reconciled in actual practice.

Similarly on the level of Scotland, the practical interests and requirements of forestry or fisheries, of agriculture or manufactures, are being set forth, and notably, for instance, the rival projects of the great Forth and Clyde Ship Canal, which so many circumstances, alike commercial and naval, are again combining to bring forward.

The practical economics of the Empire and Europe, even some outline of the Geotechnic possibilities of the world, are similarly being sketched. For the illustration of associated practical and experimental beginnings analogous to those of Edinburgh have been selected some aspects of the practical economics of Cyprus —chosen as a geographical and historic, racial and social microcosm; and as a unique region which, while practically a portion of the Colonial Empire, at once unites many of the most characteristic developments and problems of the Old World, since still, as of old, linking Europe with Asia, and both, through Egypt, even with Africa.

In such ways the methods of the Outlook Tower come to unite scientific and educational aims with practical and public interest. It seeks not only to draft and outline, but even graphically visualise, a synthesis, an encyclopædia of ordered knowledge, and similarly to outline a correspondingly detailed *Synergy* of orderly actions. Regional Survey thus passes into Regional Activity, Regional Development. Hence the geographer, whose maps have so long recorded and prepared the (*Regional*) game of war, may here increasingly look forward to no less concrete and detailed regional organisation of the productive energies and possibilities of peace. And it is only in some such concrete way as that here proposed that the present widely discussed aspirations towards checking the spread of militarism can be effectively realised, or even concretely discussed.

III. In Bristol at this moment are all the elements of a thorough Regional Survey, and this not only with map and guide-book. The observer of artistic temperament may start from the Clifton Camera, with its outlook of colour and stone, the very ideal of impressionist art, while the more strictly geographic outlook is that of the Cabot Tower, with its admirable orientation brasses, pointing not only to the city and the remoter prospect, but to the British Isles and the world of imagination and discovery. Among the papers read to the Sections of the British Association are a notable (and yearly increasing) proportion which take up each its part of a definite survey of this or that region, magnetic or meteorological, geological or biological, anthropological or industrial, economic or photographic; and these now need co-ordination in a Regional Survey of Britain. The excursions of the Association are thus not only the needful recreative and social elements of the scientific gathering, but also (with all respect to presidential addresses) the most synthetic ones. Each excursion is thus a double lesson: first in investigation in many separate sciences, but next in reuniting the results of these into the living unity of Geography, which thus rises from the accurate specialisms of the cartographer and relief-maker to the survey and interpretation of the whole living world of Nature and of man.

The bearing of this principle of Regional Survey and the use of practical centres, such as the Outlook Tower affords, is thus a great and increasing one. The past generation has been occupied with the foundation or development of innumerable schools and colleges, of scientific and technical institutions of all kinds. But the incompleteness of such contributions to intellectual or practical progress, as also the rivalry of our methods of education, here 'classical,' there 'scientific,' there 'technical,' alike tend to disappear as they become Regional.

Starting, then, from our own doors with an extending Regional Survey, and with corresponding practical activities of home and school, our education becomes once more, and that literally and concretely, the leading out of not only the passive but also of the active powers. The varied educational resources of each region or city, however extensive, thus require for their unity and completeness the establishment of institutions corresponding to the Outlook Towers of Edinburgh and Bristol, and, like them, accessible both to child and citizen.

WEDNESDAY, SEPTEMBER 14.

1. *The Orthography, Location, and Selection of Names for the National Maps. By* HENRY T. CROOK, *Memb.Inst.C.E.*

The method of determining correctly the location or orthography and relative importance of place names for the national maps is a branch of cartographical science which has scarcely received the attention its importance merits. With the greater number of names which must appear there is no difficulty. It is with the names of smaller places, detached houses, farms, and ground features of the remoter districts that the difficulties arise, yet the correctness of these is often of equal importance topographically to those of populous towns and well-known places.

The Ordnance Survey system of obtaining the opinion of three persons in the locality as authorities seems rather haphazard, for no qualification is required in the authorities, nor does the ultimate selection in case of difference of opinion appear to be anything better than empirical.

The Committee of Inquiry into the Ordnance Survey in 1892–93 paid little attention to the subject except in the case of Welsh names, in which they consider the system had not been altogether a success. The errors in other parts of the kingdom largely arise from analogous causes to those investigated—namely, from misunderstanding the local dialect or pronunciation. Wales and Scotland only present the difficulties in a more acute form.

The errors in names in the first map of Scotland led to the adoption of a method for that country which is a step in the right direction—namely, seeking the assistance of local societies, in this case the Royal Scottish Geographical Society. This principle carried out still further by the reference of doubtful names to more strictly local societies, or a body constituted from them, is desirable. But if local knowledge is desirable in the case of the orthography of place names, it is not only desirable, but essential to success, in selecting the names for the smaller scale maps. The present method is a failure, as witness the new one-inch maps in Lancashire, where not only are the names of important places omitted or wrongly placed, but the selection of names which do appear is generally unsatisfactory. This arises from the modern method of producing the smaller scale maps—viz., the mechanical reduction from the larger scale. It is stated that the names on the smaller scale maps are gone over on the ground, but the revision seems perfunctory. It does not prevent serious error. The revision of the survey generally should have been carried out from local centres, where local knowledge and experience would have had their due weight.

2. *On the Employment of Balloons for Geographical Research.* *By* Capt. B. BADEN-POWELL, *Scots Guards.*

Many difficulties beset explorers in wild countries. Much time has to be devoted to the journey, transport of supplies, hostility of natives, progress through jungles, marshes, and rivers. Hot and unhealthy climates, or extreme cold, all present great difficulties. There is, however, one high road which leads unobstructed to all parts—the air. An aëronaut, seated in the car of a balloon, floats along above all impediments and obstructions, travelling day and night at the speed of the wind, and with an extensive view of all the country below. But there are two practical difficulties to be overcome. First, the balloon travels wherever the wind chooses to take it; secondly, no free balloon has as yet ever remained up longer than a day or two. Various methods have been suggested to overcome these—propelling the balloon, utilising variable air currents, and sailing with a guide-rope have been tried for directing, while for keeping a balloon at given elevation vertical screws, compressing pumps, and guide-ropes have been devised, the latter being the most practical solution. Actual leakage of gas is not a serious matter with a good balloon, as sufficient ballast can be carried to compensate for it. Man-lifting kites might be used instead of a balloon, but the trail-rope would probably have to be of such a weight as to prohibit its practical use. Before deciding on the details of a balloon outfit for such a journey, the locality must be named. Egypt presents many most desirable qualifications: steady winds prevail up the Nile, the deserts on either side are most favourable ground for trailing over, Cairo forms a well-supplied base to start from, and the longer the journey is continued the more interesting does the country become. The most suitable equipment for such a country would consist of several balloons supporting one car, an awning spread over the top, a lightning-conductor, a large sail, and a long and heavy guide-rope; the car boat-shaped and waterproofed. The total capacity of the balloons should be about 100,000 cubic feet, capable of lifting nearly 7,000 lbs., which weight allows for four men, provisions and water to last thirty days, and instruments, arms, &c. The leakage is estimated to necessitate the discharge of about 140 lbs. daily, and the consumption of provisions and discharge of the ballast taken would enable the balloon to remain in the air, if necessary, for over three weeks, during which time it might be expected to travel some 6,000 miles.

3. *The Use of Electric Balloon Signalling in Arctic and Antarctic Expeditions.* *By* ERIC STUART BRUCE, *M.A. Oxon., F.R.Met.Soc.*

The absence of means of intercommunication is one of the most distressing deprivations which befalls the Arctic and Antarctic explorer. In Dr. Nansen's recent expedition, the want of some bond of communication between the drifting ship and a party leaving the vessel for only short excursions was severely felt, and greatly restricted the researches of the expedition. A means of communication would be afforded by the system of electric balloon signalling invented by the author, adopted for war signalling purposes by the British, Belgian, and Italian Governments, and lately adapted to the wants of Arctic and Antarctic exploration. Signalling with flag or lantern from the car of an ordinary captive balloon, worked from the deck of a ship, is possible, but such a method necessitates a large balloon with its cumbersome accessories, and is therefore impracticable in Arctic expeditions. In electric balloon signalling, the signaller and most of the apparatus remain on the ground or deck of ship. Since the weight of the car, signaller, and apparatus is abolished, the balloon can be of such a moderate size as to be practical. The apparatus consists of a balloon made of a translucent material and filled with hydrogen or coal gas. In the balloon are placed several incandescent electric lamps in metallic circuit with a source of electricity on the ground or deck of ship. In the circuit on the deck is an apparatus for making and breaking contact rapidly. By varying the duration of the flashes of light in the balloon, it is possible to signal according to the Morse code. In the signalling key there are carbon contacts, renewable when worn away by sparking. The key is placed on a switch board, which is provided with a means of turning the current on to the lamps in the balloon, either through the key or directly for continuous illumination. The speed of signalling depends entirely upon the thickness of the carbon filaments in the lamps.

The material selected for making electric balloons that are designed for Arctic work is goldbeaters' skin, which is light, strong, and retentive of hydrogen. The smallest size goldbeaters' skin balloon that would lift the lamps, and a sufficient quantity of cable to be useful, is seven feet in diameter, and having a capacity of 150 cubic feet. It takes little over one tube to fill it.

The electric incandescent lamps inside the balloon are supported one above the other on a holder made like a ladder. This form of ladder is convenient for admission into the narrow neck of the balloon.

The electric cable combines lightness, flexibility, and current capacity, being made of strands of copper, both leads being enclosed in one waterproofed outer insulation. The source of electric power for lighting the lamps in the balloon would probably be the dynamo, with which every future exploring vessel will probably be provided, and which can be efficiently worked with wind or hand-power. If a balloon and accessories is taken from the ship by an excursion party, light and portable storage cells can be used. The gas for filling the balloons can be compressed in steel cylinders, or a portable apparatus can be used for making the hydrogen on the spot.

This system of signalling makes the signallers fairly independent of the configuration of the country. An electric balloon ascending from the deck of the exploring vessel would not only act as a beacon guide to exploring parties, but would flash signals relating to the drift of the ship or any other desirable communication. If an exploring party could take another balloon with them, complete intercourse could be established. If the 'Fram' had had an electric balloon afloat, it would have been probably seen by Dr. Nansen when he was returning from his journey north, and possibly a long and perilous march might have been avoided. An electric balloon would have been an important addition to an Arctic station such as Elmwood.

The electric balloon has been successfully manipulated, not only in calm and fair weather, but in half a gale, a snowstorm and mist; signals have been read and answered in spite of these adverse atmospherical conditions. Arctic records, however, include a large proportion of still and clear weather.

Continuously illuminated, and sent up a short distance from the ship, the balloon would also be serviceable as a light for working parties, because of the diffusion of light from the large surface.

Regarding the distance to which signals may be transmitted, it is reasonable to expect that, given a sufficient altitude, a high candle power, and a clear atmosphere, through a telescope the flashes would be visible some 80 or even 100 miles.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—JAMES BONAR, M.A., LL.D., F.S.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

Old Lights and New in Economic Study.

FOR many years after the founding of the British Association sixty-seven years ago, it furnished to serious and mature students of various branches of science their chief, if not their only, opportunity of meeting one another in large numbers to compare notes and discuss suggestions. The press and the railway were not then what they are now; and it may be thought that the purposes which the Association was formed to fulfil are now fulfilled equally well in other ways. One advantage, indeed, remains unimpaired; devotees of one special study are reminded that there are other studies than their own; they are in presence of a federation of sciences more or less dependent on one another. Apart from this, an itinerant association may be of particular service to economic students. They enlarge their vision by changing their place of sojourn. They realise better that the life of the English nation is in many respects more active in the provinces than in the metropolis. Students of other subjects may be, as it were, detached from locality and have the whole world, or at least no particular part of it, for their hunting-ground. But there is a sense in which the economist or statistician lives by the localities. They present him with experiments ready made on his own chosen field, whether sad or glad, whether showing the dubious, if not disheartening, effects of foreign bounties, or the encouraging results of wise municipal enterprise. The visitors and the visited ought both to learn from one another, if such meetings are not to be wasted. Economic students at Bristol will have themselves to blame if they do not discover that students from other quarters would be in league with them, and desire both to get encouragement and to give it.

Bristol is the city not only of the Cabots, Canynges, Colston and Draper, Chatterton, Hannah More and Southey, but of John Cary, Josiah Tucker, and Edmund Burke. It has twice before this year been the meeting-place of the British Association—in 1836 and in 1875. On the last occasion the Economic Section was under the presidency of the distinguished statistician, Mr. James Heywood, but lately gone from us. It held some important discussions. Professor Jevons repeated his appeals, first made in 1865, on the subject of the Supply of Coal, and read his paper on the Influence of the Period of Sun Spots on the Price of Corn. The reasonings of the second paper are not now regarded as conclusive; economic periods are not to be strictly determined by physical alone. But the warning of Jevons, that we must expect to be straitened in our supplies of coal before many score years, is still sounding in the ears of our public men, and, when they have any leisure to think of remote evils, they nervously anticipate a time when British progress will be slackened through the abridgment, or, at least, the inadequate expansion, of British resources. The one tangible effect of the warning has been a somewhat speedier reduction of the National Debt.[1] The lessened growth of population makes that reduction less marked, but it gives us at least a slightly better prospect of moderating our own inroads on our coal and iron, while the United States, our principal rivals, will soon need all the warnings that our national candour has so freely bestowed on ourselves. It is not a year (Dec. 14, 1897) since Mr. Leonard Courtney directed the thoughts of the Statistical Society to the prophecies of Jevons. He considered them to have been fully justified by the events of the last thirty years. Even so, he did not recommend any great self-denying ordinance, any curtailment of consumption on a great scale for the sake of future generations. We may by-and-by come to hold that the stationary state is better than the progressive; but every generation believes that for itself the progressive is the better, and we may be sure every generation will use its materials when they are there. It will probably be long before we are all convinced that a State Coal Department is as needful here as a Department of Woods and Forests in India. Nothing but the logic of compulsion will persuade large bodies of men to suffer the hardships of a scarcity; they are very unlikely to deny themselves, when the rewards of the sacrifice are not for them, it may be not for theirs, not quite certain, and quite certainly remote.

Seventy years before Jevons first wrote on the scarcity of coal, Edmund Burke wrote on a scarcity which, at least till the present year, may have seemed to us past and not future—a scarcity of corn. We have been reminded in the earlier months of this year (1898) that such a scarcity is not entirely laid behind us yet, and we may aptly, in Bristol in 1898, call to memory Burke's 'Thoughts and Details on Scarcity, originally presented to the Right Honourable William Pitt in the month of November, 1795,' near the close of Burke's life.[2] Burke represented Bristol for six years (1774-80), suffered for Bristol because of America, and suffered at Bristol because of Ireland. In this pamphlet Burke boldly stated a new economic policy, or at least an economic policy which gained quite a new importance when announced, as it was, by a statesman of the first rank addressing another of as nearly equal rank as a man of great talent can be to a man of genius. It is rare for economists to exercise a direct influence on politics. In our own time we have witnessed this phenomenon, perhaps, only in Holland and in Austria. In our own country few of our economists (Jevons being one of the few) have had even as much power over the House of Commons as Bagehot over the Money Market. But Burke, in this pamphlet, was economist and statesman in one.

The result is curious. Neither Adam Smith, nor Malthus, nor Ricardo ever set down so roundly what is sometimes called the dogmatism of the older economists as Burke has set it down in this pamphlet. Burke was a great part of the political life of his time, and, like Gladstone and Bismarck, he remained so even when he seemed to have quitted the field of action. The popular idea of the dogmatism of the older economists may have been shaped to a large extent by the words of those of their followers who were statesmen, and of these Burke was the chief.

Burke is writing against the proposal to regulate wages by law and adapt them to the price of food. He opposes all interference with farmers and corn-dealers. He is against public granaries. He rises finely above prejudice when, after saying that the poor are only poor because they are numerous, he adds that the rich are dependent on them, rather than they on the rich. 'The rich,' he says, 'are trustees for those who labour, and the hoards of the rich are the banking-houses of the poor.' We agree less when he goes on to tell us that, since 'labour is a commodity, an article of trade,' the interest of the buyer and the seller thereof is, as in other contracts, one and the same so soon as the contract is concluded, every contract being necessarily a compromise in which both parties sacrifice and both gain. Thus the interest of the farmer and the labourer is not only one by the special nature of the case; it is one and the same by the laws of

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[1] See *Letters and Journals of Jevons*, 1886, p. 224, &c.

[2] Reprinted by the Charity Organisation Society, July, 1893.

commerce, which are 'the laws of Nature,' and therefore 'the laws of God,' and Government must not interfere in the matter. But, alas! he sees Government is too likely to interfere more and more, instead of less and less; and, as France has had its evil day, there is a time coming for England too—its day of distress and judgment.

When we hear these words we feel that we are dealing with a man whose 'thoughts' are not ours, though his 'details' show us how little the world has changed. The thoughts, however full of exaggeration, are those of the older economists; and political economy has passed through a severe ordeal since it seemed to triumph under these leaders. In 1846, in the repeal of the Corn Laws and the general abandonment of Protection, it won a great political victory only to suffer political eclipse; it lost its attractiveness for statesmen. It could no longer pose as the giver of plenty to a hungry people. It remained in a position of respectability without power. Like a party in opposition, it was probably none the worse for its obscurity. Work and discipline went on more steadily; honour and emoluments are not always the best inducements to the study of truth. About the fact of the effacement there is no doubt, and as little doubt that it came partly from the general impression that economists clung to obsolete theories of bygone generations, such theories, for example, as were contained in Burke's pamphlet.

Ever since we gave up (if we ever held) the belief in the infallibility of the older economists we have been trying to make up our minds about the value of their achievements. To call these men 'classical' is perhaps to beg the question. 'Classical' suggests that they are a model for all time, especially in manner of writing, and it suggests that they rule our thought as Plato and Aristotle still govern the thinking of philosophers. Perhaps the second idea has truth in it, though it must not lead us to accept those economists, any more than these philosophers, uncritically and with the halo of the unknown surrounding them. We are, after all, nearer to the old economists than we are to Plato and Aristotle. Deference to them, or even reference to them, is often set down to the illusions of antiquarians. But the strata of human thought are as worthy of study as the strata of the earth; and if, like the geological, they contain fossils, the fossils are relics of our own past life, which we should surely recover if we could.

Some 'earnest students,' especially among our more cautious and prudent philanthropists, lament that they cannot feel at home with the older economists, while nevertheless they think they owe more to the older than to the new. They have certainly one experience in common with the older. For the most part the opponents of the older in regard to the relief of the poor made more use of sentiment than of logic. Now, when a man is trying to work out his own view logically, even from imperfect premises, he is not willing to be stopped by appeals to feeling; such appeals are more likely to make him sure he is right than to suspect he may be wrong. The emotional person may prove in the end to have had a good case; some facts that the man of intellect has missed may have been dimly present to the man of feeling. But it has been a dim presentiment; and too often the perceptions, and especially the conceptions, have been clouded by the emotion. The appeals of the man of feeling are not, as in real eloquence, logic rounded off with emotion, but emotion rounded off with an appearance of logic. Economists need to entertain him with caution. Men who are trying to make their studies scientific cannot put confidence in feelings; emotion may be itself an object of study, a factor to be taken into account in investigation, but it is no instrument of study. The older economists were among the first to see this, as well as to recognise that the phenomena of society, more particularly of poverty and wealth, ought to be studied with the thoroughness and seriousness of science. The repulsiveness of their writings for many of our philanthropists has been largely due to this severe and stoical virtue. Men of strong feelings are unwilling to depend on reasoning and observation, facts, figures, and arguments alone. They count it all dry. In the Baconian sense, economic study can never be too dry; with all our efforts we can never make it dry enough, for the dryness means absence of prejudice, the endeavour to see cause and effect, reason and consequence, as they really are.

Our prudent philanthropists have this endeavour after a dry light in common with the older economists. But, even so, the latter seem to live in a different world; their thoughts are not our thoughts. How is this?

It is partly because we live in a world that has been much altered since they left it. This is a phenomenon we can observe in our own half of the century. At the end of their half of it, John Mill, who was almost one of them, spoke of Ricardo and the rest as 'old;'[1] and now John Mill is old to ourselves. Nay, we say to ourselves in reading Jevons or Bagehot that a good deal has happened since they wrote; and if, instead of taking up the books of men who died in their prime, or before it, we read the early works of men who outlived their reputation or lived oblivious to the world's changes, and wrote in 1890 as if they were still in 1850, we understand that an economist does not need to have died in order to have become antiquated. To a growing man his own thoughts of twenty years ago seem already old, but they are the thoughts out of which the later have sprung, and they are not outgrown in the sense of cut away and discarded. Neither can we cut away and discard the thoughts of the older economists, which we may think, perhaps rightly, that we have outgrown. Ours are but the newest branches of their tree of knowledge. Our thoughts are not their thoughts, but our thoughts have grown out of their thoughts. If we had lived for 100 years and been as good men as they the whole time, we should have begun with their thoughts and ended with our own, and we should not have felt the last to be alien to the first; and, even as it is, the growth has been continuous, though it be less easy here to discover all the stages than it is in the case of a single mind in a single man.

It is true that a great deal more than mere lapse of time creates a feeling of separation and distance. If the writings, even of a great author, happen to come immediately before years of rapid changes, the intervention of the changes—say the French Revolution or the introduction of railways—cuts us off from our author more effectually than if the years between us and him had been the long, slow, and blissful years of unbroken political and intellectual peace. We find it harder to judge whether our want of sympathy with him is due to our bias or his, and how much of it is due to the changes in the world he lived in which make it not quite the same world as ours.

Then the imperfection of all human records cannot fail to make the judgment of the past somewhat more fallible than of the present. Presumably a man puts his best thoughts into his books; but he does not always tell us there how he arrived at them, and unless he is a living author he cannot be cross-examined. We are often unable to see what led him to start where he did and stop where he did, or what terminus he was keeping in view. In the case of an old book we often find it hard to know how much was, in its day, taken for granted by every writer as an article of ordinary faith and common-sense. What Hooker says of the Bible applies to all writing whatever, even if it is comparatively near our own day; we must make allowance for all that was assumed as the usual mental furniture of writers and readers at the time of writing. Investigation, owing to the shortness of human life, cannot extend with equal thoroughness to all subjects at once, even of one class; and we need to know what were the subjects which our writers had tacitly agreed to let alone. This is precisely where the older economists perplex us a little. Many of their articles of common-sense have come nowadays to be regarded as prejudices. They seemed, for example, to count it part of the nature of things that one large section of society should lie at the mercy of another; it hardly struck them as a surprising phenomenon demanding inquiry. The philosophical maxim that men should never be means to an end, but should always be ends in themselves, has more credit now than it had a century ago; and the assumption of the older economists that men are and must be instruments in each other's hands gives to ordinary people the notion that these economists were of like passions with the politicians who supposed all men to be merely pieces in their game. The old economists were quite aware of the instinctive dislike of every man to be the tool

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[1] *Pol. Econ.* iv., vi., § 2, p. 308 (1848). Cf. *Autobiography*, p. 230.

of another. They made concessions to it in the matter of slavery and forced labour of all kinds. Their armoury had weapons against the pressgang and the *corvée.* When there was no physical compulsion their misgivings slept. But, at present, most of us feel that such a test is too rough and ready. One man may be the tool of another under an oppression and compulsion that are not less severe because not exercised by brute force; for example, there is the reluctant service under a hard taskmaster, only rendered because penury and starvation are the alternatives. To the older economists all kinds of subjection except that arising from the legal property of one man in another were worthy to be tolerated, and were in most cases regarded as inevitable. They had sympathy with the poor according to their knowledge, but our sympathy is probably greater because we have better knowledge of the condition of the poor. Reluctant subjection of one man to another, though a fact of everyday life now as then, does not now leave us indifferent. Willing subjection is also a familiar fact. It does not seem hard to us to acknowledge our leaders and bid them take us and use us as their instruments. But, between the extremes of (*a*) free subjection to a leader and (*b*) the submission of a slave who has no choice in the matter, there are in our society various grades of subjection to others, subjection for their ends chiefly, for our ends partly; and they cannot be split into two simple groups by a physical test. Industry especially gives plenty of instances of the temporary subjection of one man to another for definite ends and over fixed periods of time. We can hardly cope with Nature successfully at all without combining against her under leaders. It is certainly an essential feature of our present industrial system. As a man commits his goods to be used by another for him, so he commits his person to be so used, for another's benefit, but also for his own.

Now that slavery is gone, it has become as hard to prove a complete 'expropriation and *exploitation*' of the labourer in industry as it is hard to prove plagiarism in literature. The degree of the '*exploitation*' must always be considered. Were the relations of employer and employed those of Prospero and Caliban, or of Prospero and Ariel, or only of Oberon and Puck? There are many degrees, and it is a long way from the top to the bottom of the ladder. In an army the leader is not using the led for his own purposes; though he has soldiers under him, he himself is a man under authority; and he is using them for a common cause, which both have at heart. Such service is not servitude if the cause is really at heart on both sides. So it might be, and is sometimes, in industry; but we have at present, perhaps, more of the worse degrees than of the better. There is little liberty and much servitude when the workmen have no interest but their wages; they are used directly for another's ends and only indirectly and accidentally for their own. The leaders and the led can justly say of each other: they are nothing to us but means to our ends, our profits, or our wages.

The old economists took little note of such distinctions. It seemed enough to them that there was a legal contract. Even Burke, who spoke in his first pamphlet (on 'Natural Society in 1756') of the 'slavery and burdens of the poor,' and of nine out of ten of the human race as passing their life in miserable drudgery, speaks in this last pamphlet (in 1795) as if there was no cause for misgivings in this connection; a contract once made could not be a hardship to either party, for a contract is a compromise, both giving and both taking what seems the best possible equivalent at the time.

Yet in almost all contracts there is what Professor Pantaleoni[1] called lately 'economic strength' on the one side; and there is 'economic weakness' on the other. It is where the weakness is great that the contract galls even if it has been the less of two evils; and there appears to be as much servitude as liberty. The weaker is made the tool of the stronger, the tenant of the landlord, the workman of the employer, the clerk of the merchant. Professor Pantaleoni, with his ingenious casuistry, would persuade us that we can seldom pronounce on which side the economic weakness lies, especially if we look to the future as well as the present. He gives us many instances where the tables can be easily turned. Like the Platonic Socrates arguing in the 'Republic' against any sure definition of the

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[1] *Economic Journal*, June, 1898.

interest of the stronger, he hints that the antithesis can hardly be used with confidence at all.

But a broad distinction is not unlawful or useless because there are border cases that elude it. The vegetable world may be broadly distinguished from the animal or from the inanimate, although there are equivocal creatures on the border lines. So here in the industrial world we can make broad distinctions and preserve them with a little care till we come to the border. If we interpret economic strength to mean independence, we find that in most contracts the strength is ascertainably greater on one side or the other; and it might be argued that contracts are healthiest in proportion as the parties are nearest to equal independence. It is desirable that they should be independent, not indeed of all authority, but of the power of one another, so that neither shall be master, though the one may be leader and the other may agree to follow. A large number of men, perhaps the majority in civilised countries, are without this independence. It belongs, indeed, not only to those of large possessions, but to all of great talents sure of their market. It belongs, in a less degree, to ordinary skilled labour. But it does not belong to the man possessed of an unmarketable talent and no second-rate powers that are marketable. It belongs hardly at all to the day labourer, especially if he has given hostages to fortune; his dependence is such as practically to fix his fate in the world. 'A porter or day labourer,' says Adam Smith, 'must continue poor for ever.'[1] His dependence perpetuates itself.

Some modern economists have been so impressed with this overpowering influence on the poor of their poverty that they have been tempted to make it the chief factor of all history. Where there is no land to be had for the asking, they say, or where there is no common ownership of the means of production, there is necessarily weakness or dependence on the side of the employed. The causes of this dependence are the causes that have made civilised nations what they are, with all their institutions, political and social; economic causes are the supreme controlling, and even originating, causes of history.

If this were so, political economy, which began, like all other studies, by being nobody in the world and after much toil was recognised indeed but only as 'slight, unmeritable, meet to be sent on errands,' rather as a phase of wisdom than as a branch of science, would end by being the only authority of any consequence. This position, very trying to its natural modesty, is one which it should not be flattered into hastily accepting. We must not carry into science the methods of social revolt and say with the disinherited, 'Since you grant me nothing, I shall claim everything.'

It is no question whether economic conditions are one cause, but whether they are the only real cause. That they are one cause is so evident that the earliest theorists have paid regard to them. They have been ignored only in countries where Nature has made livelihood easy, and man can with an easy mind take no thought for the morrow, or for food, raiment, and dwelling. Elsewhere the struggle for existence has never passed without notice. Wherever there is a marked distinction between rich and poor, the economic factor in human life is sure to acquire great importance; and thoughtful men who are preoccupied with the discomforts of the poor are ready to count the economic factor the most important, the leaven that leavens the whole lump. This preoccupation is at the bottom of nearly all Utopias, even the Greek of Phaleas and Plato. Once arrange the production and distribution of wealth, and all other blessings will be added unto you; that is the tone of them all. Sir Thomas More, whom we might call the Archon Eponymus of modern socialists, would as a devout Christian have disclaimed such materialism; but in his own Utopia the chief peculiarities are the economic. The exaggeration is one into which we easily slip if we gaze only on the truth that circumstances and surroundings greatly influence human life; we become astonished that kings and governments have so often neglected this truth, as if it were the only truth that they have neglected. It was in this way that Robert Owen was led to overstrain the facts; and socialists as a body have taken no special pains to avoid

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[1] *Lectures*, p. 223.

exaggerations which could add a rhetorical force to their claim for a radical change. But it has been left for very recent writers not almost but altogether to ignore the influence of the spiritual environment, and to declare the material surroundings to be not merely a great part but the whole, wherever the institutions of society are concerned. This was first done by Marx and Engels. It has been done lately by Professor Loria, and Professor Patten betrays an inclination to follow the same course, though with more caution.

If our friends by their new 'economic interpretation of history' had meant no more than the late Thorold Rogers by his, we should have little ground of quarrel. The past generation has seen the historical and the theoretical economists reconciled. We all acknowledge now that too little weight was attached to changing historical conditions by the older economists; and, on the other hand, a new light has been thrown on history by a closer attention to economic conditions. It was shed by Adam Smith in his account, for example, of the decay of feudalism. Buckle, too, cast a glimmer of it. It must of course be remembered that what we read between the lines of history is not itself necessarily history. But we must leave it to historians to punish the shortcomings of historians; and we must for our part confess the failings of the economists. The older economists sometimes mistook the peculiarities of their own epoch and country for invariable attributes of humanity. The task of their successors has very largely been to decide which of their 'categories' are really historical and which permanent. This is in great part the meaning, for example, of the restatement of their doctrines by Professor Marshall and Professor Nicholson. It involves a historical interpretation of economics, to be set side by side with the economic interpretation of history by Professor Cunningham and Professor Ashley.

But the newest economic interpretation of history goes far beyond such modest rendering to Cæsar of the things that are Cæsar's. It is a substitution of economics for history, as history has been hitherto understood. Formerly we used to be told that all economics was relative to history; now we are to believe that all history is relative to economics, men having been made what they are by economical causes. Both dogmas seem not so much obviously untrue as obviously beyond testing, for if all is tainted with relativity these dogmas themselves will be so tainted, and we could not have formulated either of them without unclothing ourselves of our epoch and rising above time and circumstance. It may be the case that we do so rise and so unclothe ourselves; but there is no provision for the privilege in the premises of our theorists, and it must therefore be denied to their conclusions.

We need not have introduced this philosophical argument if there had not been a claim of universality advanced by the economists in question. Most economists are content with less than universality; they are working out a limited field with full consciousness of its limitations. The new thinkers are less humble. Their method may almost be likened to the abstract method of the older economists with a denial that there is any need for the abstraction, a denial at least that the field of economics has any boundaries.

What impressed the German socialists—Marx, Lassalle, Engels, Kautsky—was the demonstrably economic character of many political changes of the last 300 years. In the course of industrial changes the mediæval landowners gave up their power to the capitalists, and the capitalists to the employers of labour. Therefore, said the German socialists, all is due to a change in the prevailing form of production. Where agriculture prevails, we have a territorial aristocracy, a certain political system, and certain social institutions and laws; where commerce prevails we have another system; where manufacture, a third. This explains the rise of the middle classes into political power, but also the advance of the working classes as a power that will displace them and be (as we are told it ought to be) all in all. As in the economic theory of Marx and Engels all value is from labour, so on the great scale of politics all power is to be with the labouring class. Economic progress is thus the only real progress; the essence of all history is economics; the essence of all economics is labour. The steps of the progress (we hear with mingled feelings) will be for the whole world what they have been for

England, the harbour of the exiles; and the steps will be taken without deliberate human contrivance. We may look forward to the changed order as better than the present, but we cannot either hasten or retard it; it will come of itself. We cannot by taking thought add a cubit, or even an inch, to our stature.

The German socialists have not had the gracelessness to live up to this comfortable doctrine; they have agitated like other people, preparing the way for a change while declaring that it cannot possibly be hastened. Not agreeing with them in the least in their doctrine of helplessness, most of us will welcome and commend their inconsistent efforts to make the world better than it is; and they have fairly earned exemption from the title of mere theorists.

The Italian form of the materialistic view of history has been expounded with great ingenuity and learning by Professor Loria. It has excited interest chiefly in academic circles, but need not be disparaged on that account. His theory is that all progress is economic, and all economic change is due to the land and the growth of population thereon. Though he contrives to differ from Malthus, they have much in common; and we cannot discuss the theory of our contemporary without remembering that it is exactly 100 years since Malthus wrote his essay. Malthus lived to be present with the British Association in Cambridge in June 1833,[1] dying at St. Catherine's, Bath, at the end of the following year. But he first made his mark in 1798, when he grafted on economics his theory of population. Professor Loria may be said to magnify that theory even when disputing it. He thinks that, so long as there is free land, or abundance of room as well as food, men will themselves be free. No one will be economically weak if he has always the option of working as profitably for himself as for another. This is true, and we have had recent instances. Khama was afraid to sell his land lest he and his should become mere hewers of wood and drawers of water to the white men.[2] The same notion seems to have prompted the recent resistance to the hut tax in Sierra Leone. Professor Marshall, in his address to this Section in 1890 at Leeds, recalled to us the difficulty felt in the United States fifty years ago by employers who imported English workmen for their Eastern factories; the workmen moved west to become free settlers. But Professor Loria tells us, besides, how the land ceases to play this part. The growth of population leads to the disappearance of free land, and therewith of the independence that went with it. The growth of population even now leads to the pressure felt both in cities and in country districts. It affects the higher, or protected or propertied classes; they need to fence themselves about with 'connective institutions' that support their rights of property. It leads gradually to a less and less profitable production from the soil, and therefore to a less and less profitable investment of capital. These effects, in their turn, lead to a greater power of combined labourers against the employer. Professor Loria expects in the end the victory of the combined labourers, since happily the men of property are divided among themselves—agriculturists against manufacturers and traders, for example—and there is a division of the revenue. In the end there will prevail a form of co-operative labour. The labourer's option will be restored to him (though hardly, we may presume, in the form of free land), and dependence in the obnoxious sense of economic weakness over against economic strength will vanish. The Professor agrees with the Germans that we cannot work out this salvation, or even hasten it. We can only stand at a distance and behold the Promised Land.

That some such consummation is devoutly to be wished, and even perhaps hopefully to be expected, is probably the conviction of many who do not encumber their belief with a materialistic view of history. Instead of the material changes bringing the moral transformation, we may think that the moral and intellectual changes are a condition of the material reform. It seems to us to have been so with ourselves in past times; we never work better than when we believe that our future depends on ourselves, and we have not simply to wait for it. Marx and Loria allow that the automatic establishment of better conditions of life is slow and irregular. They say that the laws and governments of all civilised countries

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[1] See *Signatures of Members*, p. 36 (Cambridge, 1833).

[2] Despatch of Mr. Moffat to Colonial Office, 1894.

are obsolete, and yet persist in being. Surely, then, we might argue, there is there a strong force acting against the overpowering economic causes? Are we to wait till these old-fashioned fortifications fall down to the sound of our trumpets? Of all reformers the most irritating are those who tell us to do nothing lest we should make a mistake; but next should come those who tell us that even our mistakes can have no effect whatever. If it should appear that there is more in the way than obsolete laws, and that the laws persist because the manners and customs of the people are set fast in the same groove as the laws, then no inarticulate and spasmodic shouting should content us; we shall need the help of patient and intelligent teaching. Transformation of manners and customs can be accomplished slowly but surely by means of ideas, by the spoken word and example of life and instruction of manners. Such means have been found needful to give a people its first organisation, and will be needed, even in practical England, to organise them for the final reform, if it be the final.

We are probably too hasty, even the oldest of us, in talking of final reforms and final stages in development. We know little of development, and nothing of finality. Our experience is that every stage in civilisation, or even in economic theory, is temporary as a superstructure, though permanent as a foundation. Perhaps it is the most certain fact of the future that our best economic writings of to-day will then be dismissed as antiquated, and their diction slighted as careless English of the nineteenth century. It needs no great gift of prophecy to foresee that a hundred years hence our industrial conditions will have been much altered. The resident domestic servant, much talked of in Bristol in 1875, will probably be no longer resident. Production will be more democratic; it will be almost entirely of articles used by the masses, and hardly at all of luxuries for the rich, high wages in this way becoming really high. Working men and employers will meet on more equal terms. Whereas even now we use the term 'master' with timidity, it will by-and-by be as wrong scientifically as 'the sun's rising,' though both may remain current in the poetry of popular language. Our posterity may be living under a system of low interest, small profits, high wages, and great companies. Possibly the great companies will pass into the co-operative societies of Professor Loria's vision. It is to be feared that the advent of these, to supplant other forms of industry, is not very near. Professor Pantaleoni considers that their present counterparts have nothing in principle and method to distinguish them from ordinary ways of money-making.[1] Their triumph, however, would mean a very desirable shifting of the balance of industrial power. So far as can be seen, and we have cases in point very close at hand, a long discipline and much instruction, and many unsuccessful trials, will be needed before working men will follow leaders of their own choosing as obediently on the whole as they now submit to the direction of their employers in their industrial work. But it is an acute remark of De Tocqueville, repeated by M. Tarde,[2] that, when the 'lower' classes begin to imitate the 'higher' the distance between them must have become short, and equality must be coming near. This imitation has actually begun to take place in business as well as elsewhere. Book-keeping and knowledge of the markets are no longer the secret of the middle classes, as knowledge of the law was once the secret of the upper. Working men have shown already, in some few instances, that they can carry on a manufacture as well as a trade; and if the tyranny of great companies became intolerable we might expect that an attempt would be made all along the line to replace them by some scheme or schemes of co-operation. If such schemes were established forcibly, which is not probable in this country, we might look for a tyranny of the majority followed by a reaction, for the rule of the best leaders has its abuses like that of the best masters, and human passions seem to be more permanent than any industrial system. If such schemes were established gradually and from beneath, they might last till a better system came into view. The voice of reason and public spirit will not be fainter then than now, and will prevail even against the ruling passions of the ruling class.

[1] *Giornale degli Economisti*, vol. xvi. 1898.

[2] *L'Imitation*, 2nd ed. 1895, pp. 243, 244.

We cannot be definite in a forecast of the distant future. But it is surely not irrational to look for a larger diffusion of independence, in the sense of really mutual dependence, with a wider distribution of wealth. When dependence is mutual its sting is gone. In the future the really dependent men will probably be the incapable men, or else the men that have high capacities that are not at the moment wanted, while they have no secondary or second-rate powers on which to fall back. These two classes will give the future two problems to solve in place of some that now trouble us, but are ready to vanish away. The solution may be the public support of both classes of dependents—of the first because they are too bad, and of the second because they are too good, to work on exactly the same footing as their neighbours.

But if some such changes may be anticipated, they are to be anticipated on the terms of our present experience and of our past history; and we do not find in either that the 'economic factor' has been independent of the other factors, or has always overruled the rest. We do not find this true in our own lives as individual men. Men, as we know them, are not made by their economic conditions alone. No man is independent of these, it may be freely granted. If we do not earn our bread by the sweat of our brow we depend on the labour of another man, the wealthier, including Government itself, being, as Burke said, the pensioners of the poorer. But this material basis of all reform is not the sole constituent of the reform itself, any more than material interest is the only motive to human conduct. Both in the nation and in the man self-preservation comes first in order of time, the preservation of the material means of living. Till a man has enough to eat, he cannot work for much else; till the nation is strong for defence, it cannot think of much else. But material means of self-preservation are only the clay out of which the statue is modelled, or the stone out of which it is hewn; and the statue cannot be rightly described as a mere hypocritical disguise of the rude mineral. We cannot measure the value of a highly developed living being or group of living beings by levelling down to the component cells or atoms, on the ground that they contain the 'promise and potency' of all that followed after. Even speculative biology makes allowance for the originality and initiative of living creatures, were it only for some little peculiarity that enables each fortunate survivor to conquer a rival; it starts with two facts, the living creature and its surroundings, not with one only. So in considering the effects of economic causes we have before us not only the land but the people, not only the production but the producer. Economic causes are relative not only to outward Nature, but to the men who are confronted with it. Certain philosophers have refused because of this relativity to consider economic matters as subjects of a separate study at all, and the position has been upheld from the chair of this Section.[1] It was even common at one time to trace economic institutions to law, politics, and religion; there was no thought of counting every institution economic. Readers of Cobden will remember a passage[2] where that statesman explains the economic condition of some European countries by their religion, though Cobden can hardly be said to have any prejudice against economics. Economists have probably been right in considering that it is, on the whole, more easy to discover uniformity in human action proceeding from economic motives, whether to make a living or a fortune, than to trace it elsewhere; but this is a long way from the assertion that it does not exist elsewhere, or that the economic motives are over all persons and in all causes supreme. We may hold with Adam Smith that desire of wealth is more likely to be victorious over the whole field than any other motive taken singly or, if it be conceivable, all the rest taken together. Passion, sentiment, lust of power, and aspirations of better kinds are, however, there; and they often precede, supersede, and control economic motives, sometimes for good, sometimes for ill. Even economic selfishness is not the only selfishness, and there is a stronger motive than any selfishness, which may bind the strong one and spoil his goods. We can allow the potency of economic motives, but not their omnipotence.

We may be told that the complexity of the conditions of modern life acts as a veil to the real facts, and that what seems independent is really economical in disguise,

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[1] By Professor Ingram at Dublin, 1878.

[2] *England, Ireland, and America*, Part II.

and that in this way not only our obviously economic institutions, such as employment for wages, letting of land for rent, giving out of money for interest, but our political, and even our ecclesiastical and educational institutions, and all our prejudices and habits of thought about them, are all indirect effects of the external economic environment. It is undeniable that there are indirect effects of this cause, just as there are of religion, patriotism, family pride, or personal ambition. There are prejudices, for example, due to the character and bias given by particular occupations. Division of labour, as Comte said, is unfavourable to a 'view of the whole.' A man acquires the defects as well as the virtues of his calling. Born for the universe, he narrows his mind to the making of pin-points, and, as it were, thinks in pin-points; or, being a tanner, he thinks there is nothing like leather; or, being a doctor, he may speak as if, for his patients at least, physical health was the main object in life. The mathematician speaks as if all science were mathematics. The rights of nations and of kings sink into questions of economics if economists discuss them. But surely this reflection should rather restrain than encourage any inclination to deduce all our social institutions from economic conditions. Even if they were first modelled in clay they are a precious work of art now. We are told they are simply buttresses of established property, and therefore all the work of mere hypocrisy. This would mean that justice and singleness of heart could only be the rare products of delusion and deception; but, we know, as a matter of fact, good men are to be found, and of the same type, in all ranks, among those who have little or no property, and among those who have great possessions, among those who have great learning, and those who have none at all. There is not only some disinterestedness in science, art, and religion, a disinterestedness exemplified by the very theorists we are criticising, but on the whole it is growing at the expense of the selfishness. There are signs that, instead of buttresses of property, our science, art, and religion, and even our political and municipal institutions, are becoming better aids towards levelling; we never allow them to become the tools of a class without being ashamed of ourselves; and this proper shame is as active, we think, among economists as among any others who are trying to study a subject scientifically. It may not be true that all government is plutocracy, but it is our part to see that ours is not. If our institutions were or were not ever on the side of a single class, it is our part to see that they are not so now. The old notion that these institutions proceeded from 'a common but unknown root,' that they were distinct and mutually dependent powers, and could be neutral, adverse, or friendly, jointly or severally, in a social war, seems to suit the complicated nature of man and the complicated facts of the present day better than the idea that they are all instruments of the wealthy, and therefore rooted and grounded in self-interest and prejudice.

These venerable truisms cannot have escaped our theorists, who would probably answer as follows: That the idea of an unseen economic foundation of society is large enough to be a very concrete general principle; it includes much more than the bare struggle for bare existence; after self-preservation comes self-advancement in material wealth, the progress of the few at the expense of the greater number; the passions and ambitions of the few demand every growing material resource to minister to them; everywhere wealth is power, and it is not by accident that the most powerful nations are the most wealthy.

There is truth in this, but hardly the whole truth. Wealth does not always give power, and the power, as with Mohammedanism and Christianity, sometimes comes before the wealth. Wealth is rather the controlled than the controlling element in a healthy national polity; and the programme of nations is not drawn up with a single eye to material aggrandisement. We ourselves hold Egypt and even India not from avarice, but from love of governing; and we love governing because we think we can govern well. Our own Colonies are not bound to us by a nexus of cash payments, and our present treatment of our Colonies is not more, but distinctly less, greedy than it was before we lost the best of them nearly four generations ago. The civilised nations of the world (and not, as Adam Smith and Gibbon seemed to think, of Europe only) tend more and more to be a kind of commonwealth. The bond that unites them has in it a commercial element, of which we allow the importance. If we have learned nothing else from the

Manchester School, we have discovered the importance of commercial motives as rivals to motives of political ambition. We should allow that the interests of nations in trade are a far stronger political force now than the interests of any dynasty. We should even grant that in some new colonies, like South Africa, commercial advantage may be the ruling consideration of politics. But nations have not meaner motives than their citizens, not meaner, for example, than the motives of ordinary professional men. The ordinary doctor depends on his profession for his livelihood, and yet is anxious to help his fellow-men by relieving their suffering, and he is also concerned to serve the cause of science. If he is the best of his kind he is still influenced by all three motives. The 'economic element' is not the only or the most important in his case; in the first connection it is an end or aim, in the two others it is a mere instrument. This union of high and low interests, sublime and commonplace motives, will be found also in nations and in the history of nations. Their best achievements are not accomplished very easily without wealth, but the wealth is a mere instrument, and it may be lavishly sacrificed to accomplish their great ends. To all the better minds the charm of wealth is the power it gives to carry out a great and good work, even if it be simply the work of governing well an estate or a province. To such a man and to such a nation wealth is the material out of which the political, educational, scientific, artistic, and religious ends of life are shaped. Wealth has not created and does not control them; they and not it are the sovereign element in civilisation.

The contentions of the theorists will have had a bracing effect if they bring these old truths home to us; and we may lay to heart another lesson, that is none of their teaching. It is a well-worn saying that to straighten a bow we must bend it the other way. There is perhaps a better simile at hand. When you have heard counsel on one side you should hear counsel on the other; but you must yourself try to be judge rather than counsel in the affairs of economic study. In the time of the older economists counsel was heard for the most part on the side of the wealthier classes. The strongest economic writing at the beginning of this century was on their side—as if economists in their economics should have taken a side at all. Since then, perhaps, the opposite is true. But economists seem to have nearly learned the lesson which their intercourse here with the students of other sciences ought to teach them, that they are not to take a side in their economics; they are not to be advocates, even of the oppressed. The pleader's attitude of mind is of necessity *ex parte* and not judicial.

To preserve our judicial attitude we must have perfect freedom of criticism. We must not allow our 'institutions,' whether in art, science, or religion, to fall into the hands of one class of society, lowest or highest. We must not study our subject with a constant fear of what this rich man or even that poor man will say to what we find there. If deference to the opinions of the rich is subserviency, the more generous deference may easily slide into a love of popularity, and it is hard to say which of the two temptations is the more likely to bias the views of an economist at the present moment. Both temptations are dangerously strong, and examples will readily occur to the memory. There is danger, for instance, in endowments, unless they are made, as they happily often are, by founders who have a genuine scientific interest. Whether the wealthy founders make it the temporal interest of our professors to hold by the old views, or to adopt certain new views, the process of corruption is the same. A kind of restraint and constraint is introduced which may of course create only martyrs, but may unobservedly and insidiously have created apostates. In science, honesty is not the best policy merely; it is the only policy; without honesty there is no science. We should have no right or title to be a Section of the British Association for the Advancement of Science if we were not prepared to accept any conclusion to which the facts might lead us, in scorn of consequence; and we cannot be grateful to those who tempt us to do otherwise. Only, like our brethren in the senior branches of this Association, we must make sure of our conclusions before we proclaim them proved, and we must not cling to a theory simply because it is our own.

The following Papers were read:—

1. *A Plea for the Study of Economic History.*
By W. Cunningham, *LL.D., D.D., D.Sc.*

Though economic history proves attractive to the general reader, it has received comparatively little recognition in academic and scientific circles. But, when treated, not merely as the history of particular arts and institutions, but as the study of the material side of the life of a people, it offers a training of very great importance—

1. To the historian. Economic conditions have done much to determine the course of political history; but a mind which has been trained by the study of economic phenomena in the present is needed to detect, and to trace the influence of, economic phenomena in the past. Such training is a safeguard against false analogy.

2. To the economist. Economics is an abstract science, which assumes the conditions of modern society. Economic history gives the means of bringing the principles of economic science to bear on periods and areas, to which, as usually stated, they do not obviously apply. It thus enlarges the scope of the science, and gives its principles the real truth of observed fact, as well as the formal truth of hypothetical principles.

3. To the man of affairs. Since Englishmen are brought in contact, both as traders and administrators, with primitive and half-civilised peoples, it is important that they should understand the economic point of view of those with whomthey have to deal. It may sometimes be advisable for those who are legislating for England to fall back on mediæval experience, but this must be much more frequently instructive to those who are concerned in the administration of India or Egypt.

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2. *A Defence of Poor Law Schools.* *By* W. Chance.

Attention is first of all called to the small number of children in Poor Law Schools comparatively to the total number of children who are classed as paupers in the official statistics of pauperism. Thus, out of 225,652 children receiving relief at the cost of the Poor Rate, less than 23,500 were in Poor Law Schools, and nearly half of the 23,500 in London Poor Law Schools. The question to be considered is whether these children are being brought up so as to fit them to be independent and self-supporting in after-life. The argument assumes that the care and control of these children must remain in the hands of the existing authorities, although it would be quite possible, and desirable, to transfer the *inspection* of their education to the inspectors of the Education Department. The various methods in use at the present time for bringing up indoor pauper children are then described—viz., the two kinds of Workhouse School, the District School, the Separate School, the Sheffield system of detached houses with references to boarding-out, and Certified Schools for special classes of children. Next, attention is drawn to the kind of children which the Poor Law has to deal with, and to the special difficulties under which the managers of Poor Law Schools labour, arising from the short time which so many of the children remain in the schools; and the experience of the Swinton Schools is instanced. It would be quite impossible to 'board out' *all* the children in village homes, and therefore it is difficult to see how the Poor Law School can be replaced. The best method seems to be to arrange the school on the 'Cottage Homes' plan, or on what is known as the 'Block System,' as in the existing Girls' School at Sutton. But if the various systems are to be judged by results, the much-condemned 'Barrack' Schools seem to have done wonders, as the statistics, and, in regard to girls, those supplied by the Metropolitan Association for Befriending Young Servants, show. But 'Barrack' Schools should not be too large. It is mainly their size which has brought them into disrepute. If limited to hold not more than 500 children there is plenty of scope afforded for individualisation. The objections to pauper schools are then stated and answered, such as the 'pauper taint' which is said to attach to the children in them, their tendency to favour outbreaks of infectious disease, and the impossibility of individualising the children. Next, the many advantages which the schools possess are enumerated, and the curious fact referred to that large institutions supported by voluntary subscriptions which are open to similar objections appear to have escaped criticism altogether. The impossibility is then pointed out of having any one cut-and-dried system for dealing with the children, and the proposals of the Bristol Board of Guardians are referred to with approval. It is suggested that the idea of District Schools for country Unions is by no means played out, and that a small 'Cottage Home' community, such as is to be seen in the Eltham Union, Kent, would be a possible means of removing *all* children of school age from workhouses. The question of 'after-care' is dealt with, and the importance of it pointed out. It would not be true to say that *all* Poor Law Schools are perfect, but it would surely be better to bring all of them up to the standard of the best than to abolish the whole system. The whole question is one of *Reform* v. *Revolution.*

3. *Poor Law Administration.* *By* DOUGLAS DENT.

FRIDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Industrial Conciliation.* *By* L. L. PRICE.

Referring to a Paper read on the same subject when the Association met at Bath in 1888, the present Paper reviewed the progress of industrial conciliation during the intervening ten years. At first sight such a retrospect might seem discouraging, for scarcely a year had passed without some conspicuous industrial quarrel; but, on the other hand, public attention had been drawn to the subject, expert ability had been applied to the criticism and discovery of remedies, and experimental knowledge had been gained. Influences prejudicial to industrial peace had unquestionably been recently at work. A tendency on the part of the men to deny plenipotentiary authority of negotiation to their representatives had accompanied, and partly neutralised, an increasing willingness on the part of employers to receive and negotiate with such representatives. This was, perhaps, the fact of most evil omen for the future, and it was connected with deeper phenomena. A spirit of unrest had been abroad in the labour world, both among the new and the older unions. Socialistic aspirations had encouraged large ambitions; and the advocacy, for example, of a 'living wage,' if interpreted comprehensively, was opposed to some pacific modes of settling industrial quarrels. A reversion to older methods of policy and a resistance to improved machinery and processes of manufacture, especially at a time when foreign competition was becoming more severe, and making more dangerous that tendency to take the business of life more easily, which seemed to be characteristic of the times, was a phenomenon which could hardly be ignored; and it might even be doubted whether public opinion, which was becoming a more potent force in industrial disputes, did not exercise some influence prejudicial to lasting peace. For this public opinion was sometimes ill-informed and often impatient. It was liable to be carried away by such phrases as those of 'a living wage' and of 'collective bargaining,' which required careful discrimination. Public opinion impatiently asked for State intervention, but, in view of some recent circumstances, that demand required very careful consideration; and the experience of New Zealand was not applicable to England, except with large allowances for difference of conditions. Mediation rather than arbitration seemed still the appropriate *rôle* of the State; and the progress of voluntary conciliation and arbitration, though sometimes unnoticed, was not inconsiderable.

Two important features in the recent history of voluntary methods deserved notice: the first being the position and prospects of the sliding scale, which had been declining in favour, and the second, the growth in prominence and utility of mediation as contrasted with arbitration.

2. *Some Economic Aspects of the Imperial Idea.*

By Ethel R. Faraday, *M.A.* (*Victoria*).

The imperial idea includes not only the general notion of sovereignty native to the word empire, but the conception of international union, a meaning which the word acquired in the course of Roman and German history. The empire is therefore the political counterpart of the economic system of to-day, which is the result of a struggle between cosmopolitan and nationalist policy; the popularity of the imperial idea is a natural effect of modern economic conditions, just as the mercantile system was the natural accompaniment of the new monarchy. For a colonial empire, including communities in different stages of progress, the ideal of imperial administration is the practical expression of the economic theories of relativity and development, and of the historical method generally. With regard to the British Empire in particular, the economic aspects of the imperial idea are at present more important than its political aspects; partly because all the practicable means of consolidation—improvement of communication, organisation of defence, and Customs union—are directly or indirectly economic in character, partly because the empire as it exists is the work of economic conditions and not of political ideals. The solution of all problems affecting the prosperity of Great Britain and her colonies depends on the existence of an intelligent imperial patriotism, which it must be the work of English economists to establish. The poetical theory, according to which the imperial idea rests on the sympathies arising from community of race, history, and language, is insufficient in basis: unless the empire is to exclude some of its most loyal adherents, it must be based on sympathies transcending these. The political theory of empire advocates economic union as the preface to some undefined form of closer political union; but it is conceivable that all imperial necessities might be satisfied by economic union on the existing political foundation of allegiance to a common sovereign. In any case the fate of the imperial idea, for the present, depends chiefly upon the economist; not only because the contemporary problems of imperial organisation are mainly economic in their importance, but also because among the working classes of Great Britain the influence of the politician is diminishing, while that of the economist is increasing.

3. *Banking in Canada.* *By* B. E. Walker.

The history of currency and banking in Canada may be conveniently divided into the six following periods, of which only the last is dealt with in this abstract.

A. 1608–1760. New France. Card money and other paper issues—1685–1719, 1729–1760.

B. 1760–1791. British Occupation. Country without paper money. Coins of several countries a legal tender.

C. 1791–1812. Representative government established in 1791, but attempts to obtain charters for banks of issue unsuccessful.

D. 1812–1817. Paper money issued by Army-bill Office.

E. 1817–1867. Joint-stock banks under provincial charters.

F. 1867–1890. Dominion of Canada. Charters issued by the Federal instead of by Provincial Governments.

(For information regarding the first five periods, consult 'Banking in Canada,' by the Author, Vol. 3, 'History of Banking in all the Leading Nations,' 1896. Effingham Wilson and John Jones, London.)

Banking under the Present Act.

Term of Charter.—Charters of all banks run concurrently. Renewed every ten years, when principles and conditions of banking are fully discussed, and changes thought necessary in Bank Act are made.

Incorporation.—Terms under which new banks may be incorporated now carefully guarded. Minimum subscribed capital, 500,000 dollars. Minimum paid in, 250,000 dollars. This deposited temporarily, in cash, with Finance Department, before permission is granted to do business.

Working Regulations.—Provisions regarding rights of shareholders, powers of directors, dealing with capital stock, holding of meetings, declaring dividends, &c., are what would be expected in a well-regulated system, except in one interesting particular:—No dividend or bonus, or both combined, exceeding 8 p.c. p.a. may be paid unless net reserved profits exceed 30 p.c. of capital. No cash reserves required by law. Of any reserves held, 40 p.c. must be in legal tender notes of Dominion.

Business and Powers of a Bank.—Tendency has been to assume all powers connected with banking unless expressly prohibited. There are three main prohibitions. First two date from the earliest charter in Canada. 1. Must not engage in any other business. 2. Must not lend on real estate. 3. Must not lend on its own shares. But bankers have powers of lending on pledges of material not enjoyed by private lenders. Twenty-one sections of Act are devoted to the subject.

Statements to Government.—Elaborate monthly returns to Government. Published widely and freely criticised. Banks few in number. Weakness quickly detected. Minister of Finance may ask for special returns. List of shareholders and of unclaimed balances published annually in Blue Books.

Insolvency.—Eight sections of Act devoted to subject, but the main feature is the liability of shareholders to pay whatever calls are necessary to enable liquidator to meet all liabilities, provided such calls do not exceed the face-value of the shares held. Generally styled 'double liability.' Working of this liability in the past.

Penalties.—The Act describes many offences, and fixes penalties by fine and imprisonment.

Note Issues.—Power to issue expressed as follows: 'The bank may issue and reissue notes payable to bearer on demand and intended for circulation.' This power is subject to the following qualifications: No note may be smaller than five dollars. (Dominion Government provides smaller issues.) Larger notes must be multiples of five dollars. Total issue must not exceed paid-up and unimpaired capital. Enormous fines for breaches of this provision, whether intentional or not.

Security for Note-issues.—Notes are a prior lien upon entire estate of bank. To avoid discount for geographical reasons every issuing bank must have redemption agents in named cities of commercial importance. To avoid discount when failure occurs, all banks must maintain 5 p.c. on their average circulation in a guarantee fund held by the Government. Provisions as to how rapidly banks may be called on to replenish should drafts on fund occur. Notes of insolvent banks bear interest until liquidator announces readiness to redeem. If cannot redeem after short period, recourse may be had to guarantee fund. How has system worked? Has it provided an absolutely safe currency to the holder, and a currency bearing satisfactory relations in volume to the requirements of trade?

The Depositor.—His status as a creditor. Record of failures of banks. Proportions of capital and double liability to deposits. Growth of deposits. Government as competitors. Method of gathering deposits. Effect on development of a new country.

The Borrower and the Branch System.—Effect on the borrowing public of machinery for accumulating deposits. Moderate rates of interest. Little variation in rates over large geographical areas. Comparison with the non-branch system in the United States. Support to business public in times of stress.

Competition.—Nature of service to public. Too many banks.

Principles.—Statement of principles which underlie the Canadian Banking System.

4. *The Question of the Ratio.* *By* F. J. FARADAY.

As an ideal monetary system, bimetallism now holds the field amongst scientific economists, as recent significant adhesions have proved. The principles of free competition and reflex action, on which the theory rests, are not assailed by any of its opponents. The arguments brought in opposition to its adoption are mainly empirical and political, and a misconception of Gresham's Law. Jevons's admissions and final objection examined. Farrer's plan of 'limping' bimetallism—with paper—demands the retention of silver as currency, and, through illicit coinage implied in the system, tends to full bimetallism. Giffen's plan—or independent standards of gold and silver—also retains both metals as money. Both systems, equally with bimetallism, look to an ultimate steady relation of value between the two precious metals, and contemplate their distribution in accordance with the special monetary requirements of different countries. If the ultimate objects to be attained are identical, Farrerists, Giffenists, and Bimetallists may be equally satisfied by an arrangement which secures those objects. The attainment of such objects by the Farrerist method demands the circulation of the token coins throughout the British Empire as illustrated by the case of the Dutch colonies, and that implies a common coinage ratio. Lord Liverpool's foresight. The Giffenists contemplate the attainment of a 'natural' ratio as the condition of a permanently steady exchange with free mintage of each metal in different countries. The bimetallists demand an international legislative ratio with free coinage. In each case there is a question of ratio. If a ratio can be found which will be in accordance with the practical and theoretic bases and requirements of all three systems, agreement may be arrived at. The discussion of the ratio from the bimetallist standpoint affords the best method of making clear the scientific foundations of the system, and of demonstrating that bimetallism may be adapted to fulfil the requirements alike of Farrerists and Giffenists. Objections to the existing coinage ratios examined. The 'stimulus' of a low-valued silver ratio, and the apprehended commercial 'upheaval' with a high-valued silver ratio. The effects on the production of silver and on Indian exports and imports. Objections to a low-valued silver ratio. Conclusion: That, whether considered theoretically, statistically, geologically, or economically, retrospectively or prospectively, a legislative ratio of 15½ to 1 would be most likely to fulfil the aspirations of Farrerists, Giffenists, and bimetallists, and that under an international agreement for the free coinage of both metals at that ratio, gold rather than silver would accumulate in banks as metallic reserves.

SATURDAY, SEPTEMBER 10.

The Section did not meet.

MONDAY, SEPTEMBER 12.

The following Papers were read:—

1. *Municipalities as Traders.* *By* GEORGE PEARSON.

The writer of this paper points out the necessity of the performance of several duties formerly considered private concerns now being performed by municipalities. He then calls attention to the great growth of municipal trading as shown by the great growth of municipal indebtedness, and points out the amount of municipal indebtedness now represented by trading concerns in the hands of municipalities. He points out that municipal trading should be confined to the provision of those necessities of civilisation which are so large as to be beyond the power of individual effort to supply, and which do not form part of any Imperial Government department. He discusses the advantages and disadvantages of private, of company, and of municipal trading, and points out causes which may drive municipalities to trade to a greater extent than they are now doing. He discusses the disadvantage of trading involving the employment of a large number of workmen, having regard to the fact of the employer being popularly elected. He discusses the recent report of the Telephone Committee, particularly having regard to the suggestion that municipalities should not trade for a profit.

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2. *Ought Municipal Enterprises to Yield a Profit in Aid of Rates?*

By EDWIN CANNAN, *M.A.*

Municipalities have been likened to joint-stock companies, the ratepayers being the shareholders. If the parallel were exact, there could scarcely be any question about the propriety of municipal enterprises yielding a profit, since to make a profit is the object of the existence of a joint-stock company. How far, then, does a municipality resemble a joint-stock company?

In form the two bodies are very much alike, the management of both being committed to an elected council or directorate, and the ordinary members only interfering on rare occasions directly, though the citizens or burgesses exercise far more influence on the decisions of their representatives than the shareholders. But the basis of membership is very different. In the company it is ownership of a fraction of the homogeneous capital of the company, each fraction being exactly the same as every other fraction of the same magnitude. In the municipality it is connection with particular objects which have for the most part an individuality of their own, which are not in the possession of the municipality, but only subject to its claims for rates, and which are revalued from time to time so that they need not continue to bear the same proportion to the whole of the rateable property. The business of both the company and the municipality is economic work for the benefit of their members, but the company performs services for outsiders and distributes profits in money dividends to its shareholders, while in performing its ordinary functions the municipality provides commodities or services for its members directly, and consequently has no opportunity of making profits to be divided among them in money dividends.

As far as municipal enterprises are concerned, however, the position of the municipality resembles that of the company much more nearly. Municipal enterprise is distinguished from ordinary municipal work by the fact that the commodities or services which it provides are supposed not to accrue to the citizens approximately in proportion to the rateable value of the property with which they are connected, so that it is considered necessary to charge for them by methods and standards different from those which regulate the levying of rates. By hypothesis, then, the business is no longer a merely 'mutual' one, in which each member receives direct benefit in proportion to his share, but a business like that of an ordinary company. The municipality ought to be allowed to make a profit for the same reasons as a company is allowed—(α) in order that it may have some inducement to undertake the enterprise, which it will not have if it must take all risk of loss and no chance of gain; (β) in order to secure efficient management; and (γ) in order that the economic proportion in the production of different commodities may not be disturbed. The arguments against profit-making in municipal enterprise seem to be founded on an antiquated socialism or on a false analogy, either from co-operative institutions or from ordinary municipal work.

That there may be cases in which it is not economically desirable that the highest possible profit should be made is probable; but these cases are far less frequent than is supposed, and since when they occur the damage must be much greater to the locality than to the country in general, and also be tolerably obvious, there seems no need to restrict the freedom of the locality.

3. *Rectification of Municipal Frontiers.* *By* W. M. Acworth.

Title, of course, used metaphorically to refer to boundary between municipal socialism and private enterprise. Probable readjustment in near future, consequent on new developments of science. *Gas-light* less and less a necessity; gas exposed to competition of petroleum, electric light, &c. On the other hand, gas becoming more and more important as source of power, even on a large scale. *Water-supply* practically in public hands already; question of frontier is rather between the conflicting claims of rival public authorities. *Telephones:* suggestion of Parliamentary Committee that municipalities should be allowed to compete with United Telephone Company, and proposals of Edinburgh and Glasgow to do so. *Electric lighting:* municipalities beginning to compete with companies in possession, and companies in return proposing to compete with municipalities. *Electricity for power:* proposed distribution on vast scale from central station over great distances. Position of local authorities in reference to such undertakings, and right to compulsory purchase. *Tramways:* stunted development under municipal despotism. Electric traction, through lines between adjacent towns. What public authority can work such lines? *Conclusion:* readjustment of frontier inevitable, and probably will be in direction of widening rather than further contracting area of private enterprise.

4. *Economic and Social Influences of Electric Traction.*
By Professor S. P. Thompson, *F.R.S.*

5. *Shipping Rings and the Manchester Cotton Trade.*
By John R. Galloway.

Hostility against shipping rings having been aroused, what justification is there for this feeling? Our cotton trade should furnish evidence if these combinations have caused serious injury.

Dealing only in this paper with our exports to Eastern and far Eastern markets, it is not surprising that the volume and regularity of the traffic has called into existence first-class lines of steamships. Keen competition by outside steamships caused the established companies to form themselves into conferences for the regulation of rates and other matters. The introduction of the rebate system has enabled the various Rings to obtain control of the traffic to such an extent that shippers are no longer able to take advantage of cheap freights or routes which may be offered. This is a serious matter now that England has so many foreign competitors, and, unless she has free and ample opportunity for natural expansion and development, the very industries which are the mainstay and support of our mercantile marine may be irretrievably injured.

Taking our exports to India, the Straits, China and Japan, we examine for each market or group:—

(*a*) The figures of export from the Board of Trade Returns,
(*b*) Estimate as nearly as possible the cubic tonnage per annum,
(*c*) Calculate the rates of freight charged to shippers,
(*d*) Compare them with freights to other markets, and finally,
(*e*) Ascertain what rates are charged on cotton goods of foreign origin which enter into competition with our productions.

Bombay is the only market where combination on the part of importers has enabled them to control shipowners. Rates, which in 1881 were from 40s. to 60s. per ton, have been reduced, and for some years past have stood at 20s. 6d. per ton. The figures show that the combination has saved fully 28,000*l.* per annum for the last seventeen years. No foreign country is able to do better for their exporters.

Calcutta, Madras, and Rangoon.—Shippers to these markets are entirely under the control of Rings or Conferences. Compared with Bombay, the rate is proportionately 7s. 8d. per ton higher than it should be.

Straits Markets.—Shipping from Manchester costs 48s. per ton; from Hamburg, 22s. 6d. per ton; paid extra by Manchester shippers, 25s. 6d. per ton.

China and Japan.—Rates to these markets have gradually become dearer in consequence of the powerful Conference controlling them. Manchester shippers are at a serious disadvantage as compared with producers of cotton goods on the Continent and the United States:—Freight from Liverpool, 52s. 3d. per ton; from Hamburg, 25s. per ton; from New York, 25s. per ton.

Taking the tonnage to China and Japan, the figures show that Manchester pays 117,000*l.* more per annum for freight than would be required if the goods were shipped either from Hamburg or New York.

The question is of paramount importance to manufacturers, for high freights touch them more closely than any other party to the transaction.

Subsidies.—An examination of the circumstances in connection with the obligations imposed on steamship companies who receive subsidies for carrying mails shows that they can have little influence on the question of freights.

In view of all the facts, it is strange that the agitation against shipping rings is neither widespread nor well organised.

The chief difficulties may be stated under three heads:—

1st. Shippers are under the thraldom of the rebate system, and sums amounting to hundreds and thousands of pounds would have to be sacrificed if they failed to comply with the terms laid down by the Conference lines.

2nd. Many shipping firms, and especially the larger ones, represent the different steamship companies in foreign ports, and are quiescent from interested motives.

3rd. The greatest difficulty is to be found in the objection which shippers generally have to take common or united action on any matter affecting their interest. This, in turn, is explained by the almost fierce spirit of independence which has always characterised Manchester shippers as a body, and which in the past has produced satisfactory results. It has already been described by the word 'individualism,' and is sometimes mistaken for jealousy by those not conversant with the facts.

It is folly to adhere any longer to individualism as a working principle. Combinations are the order of the day, and it is futile to attack shipping rings unless similar methods are adopted. A Shippers' Federation is suggested, to receive on behalf of the members all rebates and returns. This may appear a small matter, but it is difficult to find an object on which shippers can unite. The expense of such an organisation should not be great. Manchester has spent 15,000,000*l.* on her Ship Canal, and the fruits of that enormous sacrifice are practically wasted, except as regards Bombay, by the action of shipping rings in preventing steamers from making use of the water-way.

Bombay natives succeeded in defeating shipowners' combinations in 1881, and similar tactics could be adopted in other markets if shippers would unite. The danger to Manchester shippers is that importers on the other side may take the matter out of their hands. A saving of 20s. per ton appeals to the intelligence of the humblest trader everywhere. Once show him how it can be accomplished, and unity of action makes it possible.

6. *The Effect of Sugar Bounties.* *By* GEO. E. DAVIES.

(*a*) *On British Sugar-Refining.*—1. Position up to 1884. 2. Fall in prices. 3. Comparison between 1884 and 1896. 4. Decrease in output. 5. Increase in German refining. 6. And its effect upon prices. 7. German bounties. 8. Bounties and British refiners. 9. The advantage to Germany. 10. Closing of some British refineries. 11. Advantages of superior methods. 12. Inferiority of partial turnout. 13. Some British refiners fail. 14. While others succeed. 15. Improvements caused by competition. 16. Official returns misleading. 17. French and German bounties.

(*b*) *On the Confectionery Trade.*—1. Development of the trade. 2. Capital employed. 3. Output and employment. 4. Position in 1884. 5. Effect on trade. 6. Not limited to amount of bounties. 7. Regularity of quality. 8. General advantages accruing.

(*c*) *On British Consumers.*—1. The consumption in Britain. 2. Advantages of best markets. 3. Beet sugar an advantage. 4. Cost of production. 5. Its effect on prices.

(*d*) *On the West Indies.*—1. The effect on the Islands. 2. Value of the West India Commission. 3. Cane and beet sugar production. 4. Old-fashioned methods. 5. Waste of material. 6. Introduction of modern machinery. 7. And reduced cost of production. 8. Further improvements necessary. 9. The yield of the sugar canes. 10. System of importation. 11. West Indian requirements. 12. Grants to West Indies. 13. Preferable to abolition of bounties.

TUESDAY, SEPTEMBER 13.

The following Papers were read:—

1. *Comparison of the Changes in Wages in France, the United States, and the United Kingdom from* 1840 *to* 1891. *By* A. L. Bowley, *M.A.*

The object of this paper is to compare the results of the recent inquiry in France as to wages and their changes 'Salaires et Durée du Travail' (Office du Travail, 1897), and of the United States Senate Report on 'Wholesale Prices, Wages and Transportation' (Washington, 1893), with wages in the United Kingdom. A paper considering the American report, and comparing the changes of wages since 1860, there shown, with the changes in the United Kingdom, was read to this Section at Ipswich;[1] the results obtained there, and in a paper relating to English wages since 1860 read to the Statistical Society in 1895, are freely used in the present estimate. The new work in this paper consists chiefly in carrying back English wages from 1860 to 1840, and in tabulating the figures in the foreign reports for comparison.

Stress is laid on the fact that none of the results obtained in the foreign reports or in the English calculations can pretend to minute accuracy. The probable accuracy diminishes as the dates become remote; as a rough guide it may be said that the index figures relating to *nominal* wages may be five in error, whether in the number sixty-one for 1840 or ninety for 1886, and those relating to *real* wages twice as far from the fact. This is unfortunate as far as theories dealing with the laws of wages are concerned, but for a general view and comparison such a margin of error is of less account. Throughout the calculations it has been recognised that the result must be rough, and fine instruments have not been used. Thus, *simple* instead of *weighted* averages have been taken; figures have not been calculated beyond the first decimal place, and slight differences of date ignored. Similar principles had been followed by the compilers of the French report, and the American figures are insufficient for very accurate deductions; hence for this comparison it is useless to labour the English figures to their greatest possible accuracy.

The general method adopted has been to form an index-number for wages, and all the theorems relating to the use and accuracy of index-numbers for prices may be adopted. In the actual work it has been found that the numbers obtained by successive approximations are such as the theory of error would lead one to expect.

The English Figures.—The sources of information for these are official reports on wages, reports of Commissions and of Factory Inspectors, reports on Trades Unions, and general or special estimates published at various times by private individuals. The information is heterogeneous and from very miscellaneous sources,

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[1] Vide *Brit. Assoc. Rep.*, p. 775, and *Economic Journal*, 1895.

but is sufficient for the present purpose. For each trade in question all the available data have been tabulated, and the *rates of change* indicated by each authority for series of dates considered. From these have been deduced series of index-numbers relating to the various trades, harmonising as far as possible all the information. In the case of Agriculture, Building, Printing, and Mining, authorities are in close agreement; for the Cotton, Woollen, and Iron industries it is more difficult to make good estimates. A table is given showing these figures. The principal results are that average *nominal* or money wages in 1840 expressed as percentages of those in 1891 were *Cotton*, 50; *Wool*, 74; *Building*, 66; *Mining*, 61; *Iron*, 77; *Sailors*, 61; *Compositors*, 79; *Agriculture*, 75. A second table is given *weighting* these averages for the general comparison, and the course of average nominal wages in this group of trades is found to be as given in the first table below. The English figures would be practically unaffected if agriculture were excluded.

It having been found in the previous work that the American figures give nearly the same result on whatever principle the averages are taken, the corresponding line for the United States is filled in with little further discussion.

The French figures require more explanation. The data appear insufficient, but are shown to be consistent with each other and capable of giving sufficiently accurate results. For many years figures are interpolated, since the French dates —viz. 1840–5 and 1860–5—and the English dates do not quite correspond, and the result is given in the following table:—

A. *Average Nominal Wages, as Percentages of those in* 1891.

Years	1840	1850	1860	1866	1870	1874	1877	1880	1883	1886	1891
UNITED KINGDOM . .	61	61	73	81	83	97	94	89	92	90	100
FRANCE	52	52	65	70	75	80	83	86	91	90	100
UNITED STATES . .	49	54	59	66	81	87	80	85	95	92	100

The attempt to estimate *real* wages by correcting for the changes in purchasing power cannot be satisfactorily carried out for France; but the following tentative results are obtained, as being those indicated by the data so far found:—

B. *Average Real and Nominal Wages as Percentages of those in* 1891.

Years	1840	1850	1860	1866	1870	1874	1877	1880	1883	1886	1891
UNITED KINGDOM—*Real* .	43	55	53	57	62	68	72	73	81	94	100
UNITED STATES—*Real* .	47	57	56	46	64	70	71	77	84	93	100

Years	1844–53	1854–63	1864–73	1874–83	1884–93	1891
UNITED KINGDOM—*Nominal* .	61	73	82	93	95	100
,, ,, *Real* . .	53	51	59	82	97	100
FRANCE—*Nominal*	52	65	73	86	95	100
,, *Real*	55	61	67	78	94	100
UNITED STATES—*Nominal* . .	53	58	72	86	95	100
,, ,, *Real* . . .	54	53	57	76	95	100

These results are all subject to correction, especially those relating to *real* French wages; but it is unlikely that further information can greatly affect the startling similarity of the course of *real* wages in the three countries. The conclusion may be stated roughly as follows:—Reckoning from 1891, *real* wages had doubled in all these countries in less than fifty years, and increased by one-half in less than twenty years. The question of the distribution of the wages of individuals about the average at different dates is not discussed.

2. *Saving and Spending: a Criticism of Recent Theories.*[1]

By A. W. FLUX.

At various times recently an old doctrine has been revived, namely, that the cause of industrial depression is to be found in under-consumption—in excessive saving. The advocates of this view maintain that the volume of current consumption strictly determines the extent of useful employment for the instruments of production; that saving beyond this limit leads, not to an increase of real capital, but merely to a multiplication of forms of capital; to a struggle between individuals for the ownership of the limited amount of really useful capital; that one man's saving tends to annul that of some other man. In view of the spread of these beliefs some portions of well-known teachings not destroyed by the contentions referred to, but which conflict directly with them, are again presented.

The doctrine that the connection between capital and consumption is such that the latter determines the extent of real use of the former is specious but untrue. The extension of consumption is a result of the increased power of production of modern times. The mutual connection between the two is not such as to say that one is an independent determining cause of the other.

The act of saving appears to be viewed by the writers to whom allusion is made as one which aims at creating forms of wealth of indefinite persistence. This is surely a strained view. Indefinite increase of saving is not dependent on the possibility of storing the saving in forms practically imperishable. The difficulty of foreseeing what forms of capital will be useful to distant generations is not only not insuperable, it does not at all prevent increase of really useful capital. The perpetuation of productive instruments is not unaccompanied by change in the instruments themselves.

It might be admitted that the amount of savings which could be invested so as to yield a return of not less than, say, 2½ per cent. net is quite capable of being surpassed. It is surely notorious that enormous fields for investment exist which might be utilised were capital available at a rate of return considerably below current rates, still more if it were available freely. Some part of what appears to be waste of capital may be incidental to the introduction of more efficient methods and more capable management.

A point urged in favour of spending rather than saving is that, whatever individuals may do, a community can never 'spend too much.' This is so clearly inaccurate as to throw doubt on any proposition logically connected with it.

It may be true that real wisdom might dictate the investment of savings, not in Consols or in shares of industrial companies or the like, but in the fuller development of the capacities of human beings—in the better preparation of children for the battle of life, for example.

That investors make mistakes in selecting their investments hardly justifies a crusade against saving and the recommendation of the contrary policy of spending as a means of curing industrial evils. A proper subordination of the desires of the present to the practically certain needs of the future is far from being attained at the present time, and the practical outcome of the doctrines criticised is to recommend aiming at present gratification rather than future benefit. For the community as well as for individuals it remains as true as ever that 'you cannot both eat your cake and have it.'

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[1] Will be printed *in extenso* in the *Economic Review*, January 1899.

3. *On Partnership of Capital and Labour as a Solution of the Conflict between them.* By HENRY VIVIAN.

What is meant by Partnership. Industrial progress and the position of Labour.

Unions of Employers and Employed. Political machinery not the best for all purposes.

Narrow motives not conducive to success of Partnerships. Early failures. Present position of the Movement towards Partnership. Examples of producers' associations organised by working men; working-class employers applying the principle; private firms applying the principle.

Difficulties in the way of progress.

Helpful agencies.

4. *The Expenditure of Middle-Class Working Women.*
By MISS C. E. COLLET.

TABLE I.—*Details of Expenditure for One Year of Six Middle-class Working Women:* (1) *a Journalist, Joint Occupier of House;* (2) *a Clerk, renting Unfurnished Lodgings;* (3) *a High School Mistress in Furnished Lodgings; and* (4), (5), *and* (6) *High School Mistresses boarding in Private Houses.*

PERCENTAGE OF INCOME SPENT ON

—	(1)	(2)	(3)	(4)	(5)	(6)
Lodging, Light, Heat and Service	13·5	19·8	13·5	36·8	39·4	41·0
Food, Housekeeping, Furniture, &c.	23·1	20·7	29·9			
Washing . . .	Included in Housekeeping	2·0	2·6	2·2	2·2	—(*a*)
Dress	12·4	18·1	12·3	9·9	15·5	10·5
Books, Newspapers, &c. .	4·9	1·3	2·1	2·8	3·6	.4
Travelling	4·0	3·5(*b*)	9·2	11·9	4·6	3·9
Holiday	2·4				4·6	9·5
Amusements	1·5	·9	2·7	—(*a*)	1·1	-(*a*)
Subscriptions, Donations, &c.	9·1	1·1	1·5	5·3	—(*a*)	—(*a*)
Presents	5·6	5·5	4·5	7·0	—(*a*)	—(*a*)
Postage and Stationery .	·9	—(*a*)	3·7	1·2	—(*a*)	—(*a*)
Miscellaneous	1·6	8·4 (*c*)	1·2	2·7	7·8	7·0
Doctor and Medicine .	Nil	1·1	·8	3·1	·7	2·0
Insurance and Savings .	21·0	17·6	16·0	17·1	20·5	25·7
Total	100	100	100	100	100	100
Total Income	£338 (*d*)	£227	£130	£138	£103·4	£100

(*a*) Included in 'Miscellaneous.'

(*b*) Daily travelling included under 'Miscellaneous;' holiday mainly at friends expense.

(*c*) Includes 'petty cash.'

(*d*) This total *Expenditure*; income tax and balance not stated; savings only include money actually removed from current account to 'a place of safety.'

TABLE II.—*Expenditure on different Articles of Dress by* (1) *a Journalist:* (2) *and* (7) *Clerks; and* (3) *a High School Mistress.*

AMOUNT SPENT ON

—	(1)			(2)			(7)			(3)		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Dresses	19	1	9	16	10	0	23	2	11	3	16	1
Coats, Cloaks, Umbrellas, &c.	2	4	0	8	10	0	2	16	0	2	7	11
Millinery	3	11	7	4	10	0	5	5	9	1	11	1
Underclothing and Handkerchiefs	6	17	8	6	0	0	5	2	1	3	9	11
Boots	6	5	8	3	0	0	3	4	2	2	15	11¼
Gloves	2	0	0	1	15	0	1	13	6	0	15	8
Ties, Collars, &c.	0	19	9	0	15	0	1	6	5	0	15	11¾
Miscellaneous	1	3	0¾		—	(*a*)		—	(*b*)	0	8	11
Total	42	3	5¾	41	0	0	42	10	10	16	1	6

(*a*) Included in 'petty cash,' and not separable from other items.

(*b*) Number 7, who lived with her parents, has not included anything in her dress account which does not come under the preceding head. Sponges, toilet soaps, brushes, &c., should be included.

5. *The Wakefield Land System, and the Developments from it in the Colonies.* *By* W. P. REEVES.

Wakefield's services to the Empire have scarcely been fully recognised. He took an important share in—(1) the successful arrangement of Canada; (2) the abolition of the transportation of convicts; (3) the granting of self-government to the White Colonies. He saved New Zealand from falling to France, and was the virtual founder both of that Colony and South Australia. His main work, however, was the revival of the spirit of colonisation within the Empire. He endeavoured to elevate colonising into an art. He found it a by-word; he left it a branch of statesmanship. He believed that the occupation of desert countries should be undertaken, not haphazard by roving pioneers and squatters, but by organised communities comprising all classes of English society. He opposed the shovelling of paupers and convicts into the empty corners of the Empire. He believed that an ample supply of wage-labourers ought to be provided for his young colonies, as only on that assurance would capitalists be induced to emigrate thither.

The first condition of his colonising system was to be a fixed 'sufficient' price for the waste lands of his settlements. These were no longer to be given away in large land-grants to squatters or the favoured friends of officials, but to be sold openly in the simplest, fairest way to applicants in order of priority. The revenue thus provided was used to form an immigration fund to provide the settlement with labour; the second, to find money for the development of the country by roads and bridges. Until the lands were sold, pastoral tenants were to have grazing rights over them, which were, however, never to interfere with free selection by purchasers at the sufficient price. Wakefield set himself to stop free land grants, and in the main succeeded. By doing so he has effected the disposition of about 120,000,000 acres of land already alienated and 650,000,000 acres leased in Australasia alone. The revenue obtained from land sales during the last sixty years has been in the main well spent, and it has been of the greatest value to colonisation. The settlement of South Australia and New Zealand by Wakefield's Associations was marked by mistakes at the outset which had no necessary connection with Wakefield's land theory, though they helped to discredit it. They were blunders of administration. Ultimately, however, both settlements were brilliantly successful, and are indebted to Wakefield for the fine stamp of their early colonists.

A land boom in South Australia showed at the outset the difficulty of fixing a sufficient uniform price which should be low enough in normal times not to check genuine settlement and yet high enough to be an obstacle to land speculation in periods of inflation. This difficulty no fixed price could fully meet. As a rule, the price was fixed too low rather than too high.

Other drawbacks to the system were the frauds, blackmailing, and class hatreds bred by the 'free selection' on pastoral runs. The best example of this was found in the working of the Robertson Free Selection Act in New South Wales. The land laws of the seven Colonies are a long series of expedients to prevent—(1) speculative purchase for re-sale; (2) the locking-up of lands in great pastoral estates. Up to 1875 the amount of success they had was small; since then it has been much greater. In Australia the laws chiefly endeavour to gain these ends, limiting the area any one man can buy by insisting on *bonâ-fide* occupation by the purchaser of each piece and on his working at the improvement thereof or otherwise forfeiting it.

New Zealand goes a step further, and retains the fee simple of the land, leasing it out on a perpetual lease at a quit rent subject to conditions as to area, residence, and transfer.

The democratic party in the Colonies have been taught to condemn Wakefield. But in my opinion they have done him great injustice. As between reckless land grants or unlimited purchasing at low prices and his system of a sufficient price the choice must be in his favour. The history of the Colonies is largely a story of economic mischief, wrought, not because land was too dear, but because it was too cheap. Superior as some of the systems now slowly evolved are to Wakefield's, the knowledge which has built them up has been dearly purchased.

In 1891, in New South Wales, 679 persons held about half the land alienated.

In New Zealand 584 persons held more than half.

In South Australia 1,283 persons owned half the alienated soil.

In the three Colonies 1,255 persons held 35,000,000 acres.

Thus the agrarian question in Australasia is, and is likely to remain, the source of acute class feeling.

SECTION G.—MECHANICAL SCIENCE.

PRESIDENT OF THE SECTION.—Sir JOHN WOLFE-BARRY, K.C.B., F.R.S.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

I WISH at the commencement of the proceedings this morning to refer to the loss which the world of science has sustained in the untimely and lamentable death of my friend, Dr. John Hopkinson. This tragedy was one of a most unusual kind, and I think I am not saying too much if I say it has touched the hearts of everybody in Great Britain. When we recognise that the father, son, and two daughters were suddenly swept into eternity by this dreadful accident, I am sure that our hearts go out in respectful sympathy and heartfelt condolence to Mrs. Hopkinson and the remainder of Dr. Hopkinson's family. To us in the scientific world the loss is certainly irreparable. Dr. John Hopkinson was a man of most unusual attainments. He was Senior Wrangler at the University of Cambridge, and Smith's Prizeman, and he had the highest gifts not only of intellectual power, but they were combined with great practical knowledge, and at the time of his death with most ripe experience. He was admired throughout the whole of his own country and the whole of the scientific world of Great Britain. But I think I am not going too far when I say he was an ornament to the world of science, whether it be European or American, and that his name was respected in every part where men of science are qualified to form an opinion upon an individual's merits. I can speak of my departed friend with perhaps stronger feelings. I have come under the magic of his personal charm; I have been able to realise his charming modesty, combined with his great attainments and his many social gifts. He was a member of the Council of the Institution of Civil Engineers, on which I had the honour of serving with him for many years, and he was a member also of the Council of the British Association. He was a personal friend of many of those who hear me, and I am sure they will agree that I have not said a word too much in bringing before this section the great loss which has been sustained by the death of John Hopkinson. I am sure I shall have my own sentiments endorsed when I offer this small tribute of affectionate admiration to a man of science who has been one of the brightest ornaments of the century.

Apart from all the other considerations which so favourably affect this Congress, I think, so far as Section G is concerned, that we are fortunate in meeting in this ancient city, which has so much of special interest for engineers and for others interested in applied science.

(I.) I propose, therefore, to say a few introductory words about Bristol and its neighbourhood from the point of view of this section of the Association, but it is far from my intention to either criticise the past work of the Corporation in relation to their dock enterprises or to volunteer advice to them with respect to possible works of improvement.

Bristol is, at this moment, of great commercial importance, as indicated by the value of its imports and exports, and occupied an even more important relative position among British ports at a time when the ports of Liverpool, Glasgow, Cardiff, or Southampton were almost or altogether undeveloped. So far as Customs revenue is concerned, Bristol now stands third, and in regard to the gross value of her sea-borne trade she is thirteenth among ports of the United Kingdom.

It is unnecessary, and it would be foreign to the objects of Section G, for me to attempt either to trace the economic reasons which have caused the long-continued importance of Bristol, or to account for the rapid growth of other ports more or less competitive with her. All such causes are to be found, at least to a great extent, in considerations apart from the merely physical characteristics of the sea, river, or land at the various sites, as, for example, in propinquity to markets or centres of production, in situation relatively to population or to means of distribution, in individual or collective enterprise, in enlightened or unenlightened administration.

These circumstances have, in truth, at least as much if not more influence in determining the history and prosperity of ports than what are termed natural advantages of respective sites, by which I mean such matters as protection from winds and currents, depth of water in the port itself and in its approaches from the sea, the possession of soil adapted to the foundations of docks or quays, and ready access to suitable materials for cheap and efficient construction.

While recognising to the full the great advantages of such physical endowments in the development of a great port, one cannot but remember that they form only part of the problem, and that the business of engineers is to modify and direct the great forces and characteristics of Nature for the use and convenience of mankind. We have, in fact, to make the best of a locality which may or may not be promising in the first instance, and history shows us that there are few places which are hopeless for our purposes. Thus while, on the one hand, we see many harbours in this country which inherit from Nature every feature to be desired for the establishment of a port, but which remain useless for that object, so, on the other hand, we find many of the great centres of trade established in situations which possessed no such advantages, and where almost everything has had to be supplied by painful exertion and great expenditure.

As examples of these facts, I may point to the remarkable progress of many commercial ports situated in localities which were originally the reverse of promising from an engineering point of view—to Glasgow, where twenty-six millions sterling in value of exports and imports are annually dealt with in ships of the largest draught, though it is placed on a river which only fifty years ago was nearly dry at low water, for a distance of ten miles below the present docks; to Newcastle, with a present trade of 13½ millions sterling, which within the memory of this generation was approached by a shallow river, entering a much-exposed part of the North Sea over a dangerous sand bar. Sixty years ago the Tyne could only receive (and that only at high water) a small class of coasting vessels, whereas it is now navigable for deep-draughted vessels for a distance of thirteen miles from the sea. The breakwaters also at Tynemouth, which have been constructed under great difficulties, on a coast without a single natural encouraging characteristic, not only make a valuable harbour of refuge, but have, practically speaking, removed the external bar.

In a similar way, as evidence of the truth of my proposition, I might point to a multitude of other instances—to the great docks of Buenos Ayres, which city, when I knew it twenty years ago, could not be approached within seven or eight miles by sea-going ships of 15 or 16 feet draught; to Calcutta, dependent on the dangerous navigation of the Hooghly, including the dreaded James and Mary shoals; to the creation of the port of Manchester, forty-five miles from the sea, approached by a tide-locked canal which has cost thirteen or fourteen millions of money in its construction; to the great recent developments of Rouen, Dunkirk, Antwerp, and Amsterdam; to the improvements of the Danube and the Mississippi. In all of these cases the natural characteristics of the localities were quite unsuited to the requirements of an advancing trade in modern vessels, but the inexorable demands of commercial shipping have created the supply, at the hands of engineers, of improvements and modifications of Nature, which are so large and important that, to an unprofessional eye, they might now almost appear, at least in some of the cases which I have mentioned, to be physical characteristics of the locality.

I think that we may safely say that trade will produce the required accommodation, and that accommodation in itself will not create or attract trade.

Bristol is a case in point, and it is interesting to us at this meeting to note, however briefly, some of the important works which have altered and are altering its capacity as a port. At the end of last century Bristol and its capabilities were, as they have been almost ever since, the battlefield of civil engineers, and we know that reports and projects were made by most of the men who were then recognised as authorities. The diversion of the river Avon and the construction of the floating harbour of Bristol, which were carried out under the advice of William Jessop in the years from 1804 to 1809, were boldly conceived and ably executed. The result of the diversion of the Avon by means of what is still known as the new cut enabled the old course of the river to be made into a floating harbour of about 71 acres, of which 57 acres are available for vessels of considerable size. The total cost seems to have been about 600,000*l*. Though the greatest draught of water in the floating harbour (some 20 feet) and the dimensions of the original locks (150 feet long and 36 feet wide) may appear to us at the close of the nineteenth century somewhat insignificant, they were, no doubt, up to the estimated requirements of that day, and I think we can recognise in Jessop's work the impress of a great mind.

The Cumberland Basin was deepened and improved, and the lock accommodation was increased by Brunel in 1850 by the construction of a lock 350 feet long and 62 feet wide, and again by Howard in 1871, who made another lock 350 feet long, 62 feet wide, with 23 feet of water at high water of neap tides. This is the present limitation of the access of shipping to the town docks, and, though we realise its insufficiency for modern vessels, we can appreciate the energy of those who have gone before us, and who found the funds for or designed works which have for so many years well fulfilled their purpose.

The approach to Bristol from the sea—that is to say, from King Road in the Bristol Channel—is certainly unpromising for large ships, and indeed, when contemplated at low water, appears not a little forbidding. Something has been done, and further works are in progress, towards straightening, deepening, buoying, and lighting the tortuous course of the Avon below Bristol. More, no doubt, would have been undertaken in former years, if the great rise of tide in the river had not provided, at spring tides, a depth and width for navigation which were sufficient for practical purposes, until the size of modern ships imperatively demanded increased facilities of approach. I think it is a remarkable thing that vessels of 3,000 tons burden, 320 feet in length, and drawing 26 feet of water, succeed in reaching Bristol, and that the trade in the heart of the city continues to increase.

Those acquainted with the strong tides of the Avon, or with its bends, which do not exceed in places a radius of 800 feet, and, lastly, with what might be the consequences of a long vessel grounding in a channel which has only a bottom width of 100 feet, cannot but recognise the skill and nerve of pilots in the navigating large vessels from King Road to Bristol. This is done by night as well as by day, and so successfully that the rate of insurance for Bristol is no more than it is for Avonmouth or Portishead, the entrances of which are in the Severn, or than for many ports situated on the open sea.

We have similar examples of what can be done by the systematic development of pilotage skill in the Hooghly, the River Plate, in the Yangtse Kiang, the Mississippi, and other rivers where special men have been evolved, as it were, by the demand, and navigate with safety and success channels which are so full of dangers that they might well appear impracticable. Experience, indeed, shows us that, given a trade and a depth of water rendering access possible, ships will make their way to ports through all kinds of difficulties and with a wonderfully small margin of water under their keels, reminding one of the boast of the Mississippi captain that he could take his steamer wherever the channel was a little damp.

To return, however, to Bristol and the Avon. In spite of all efforts to keep pace with trading requirements, the time arrived, in 1868, for providing improved dock accommodation, which would avoid the navigation of the Avon, and at the same time afford deeper locks and more spacious quays than could be given in Bristol itself. The Avonmouth and Portishead docks accordingly were built between 1868 and 1878, and acquired by the Corporation in 1884. Both are fine works for their period; but even in their case the rapid development of modern shipping has occasioned a demand for enlargements of the facilities which they afford. Accordingly, a matter which is again agitating Bristol is still further dock accommodation, and there has been a sharp contention whether this should be effected by what is implied in the somewhat barbarous word 'dockising' the Avon, or by new docks at King Road. Dockising implies the construction of a weir and locks at Avonmouth, so that the Avon would be impounded and make one sheet of water nearly six miles long to Bristol, the natural discharge of the river being provided for by outfall sluices, while the alternative of dockising the Avon is to be found in great additions to the docks either at Avonmouth or Portishead.

In the peaceful atmosphere of Section G, I will not enter upon the various aspects of these antagonistic proposals, and will merely say that I have no doubt that in some way Bristol will keep ahead of what is wanted, and that I wish the city and the engineer who may carry out any of the ideas which may be eventually adopted every success and satisfaction in such important undertakings.

(II.) Leaving, then, for the present all local considerations, and seeing that a large part of my own work has lain in the construction of new docks and in the alteration of old docks, I propose now to say a few words on what appear to me to be at present the salient points on these subjects in relation to the growth and the requirements of our merchant navy.

In the first place, one cannot but be struck with the great demands which have come with some suddenness on the present generation for increased dock and quay accommodation. The British people are the chief carriers of the world, and are indeed those 'that go down to the sea in ships, and occupy their business in great waters.' This can be appreciated when we consider that annually our over-sea import registered tonnage is thirty-four millions, and our export registered tonnage is thirty-eight millions. Our coastwise traffic amounts to sixty-three million tons per annum, making together a tonnage to be dealt with of one hundred and thirty-five million tons. If we add to these figures the tonnage of vessels in ballast and the number of calls of those vessels in the coasting trade which touch at several ports in the course of one voyage, we must add a further fifty-five millions of tonnage, making a total of one hundred and ninety millions of tonnage using our ports yearly; and if we divide these figures by, say, three hundred days, to provide against more or less idle days, bad weather, and the like, we have the result of six hundred and thirty-three thousand tons per diem entering and leaving our ports. If we assume an average ship of three hundred registered tons, which is probably not far wrong, we have about two thousand one hundred trading vessels entering or leaving our ports daily—a flotilla of startling numbers.

In truth, the magnitude of our mercantile navy, as compared with that of other countries, is astonishing. We have ten and a half millions of tons, against a total of thirteen millions of tons belonging to all the other nations of the world, in which are included three millions of tons of steam vessels engaged in the lake and river traffic of the United States. Descending to particulars, our merchant fleet is eleven and a half times that of France, seven times that of Germany, eighteen times that of Russia (in Europe), two and three-quarter times that of the United States (inclusive of the craft on the great lakes), six and three-quarter times that of Norway, fourteen times that of Italy, and fourteen times that of Spain. Out of our total tonnage of ten and a half millions, six and three-quarter millions are steam vessels, and the proportions in relation to the steam tonnage of the other countries above referred to are approximately the same.

Again, it is instructive to note how small a proportion of the trade of other countries, even including their coasting traffic, is carried in ships belonging to the country in question. Thus, whereas we as a nation convey in steamships 76 per cent. of the aggregate tonnage of our own ports, only the following proportions of the total trade of other nations are carried by the shipping of each country in question:—

France	about	30	per cent.
Italy	„	19	„
Germany	„	43	„
Russia (in Europe)	„	7	„
Norway	„	56	„
Sweden	„	29	„
Holland	„	26	„
United States (over-sea)	„	15	„

Further, it is a recognised fact that a very large part of the balance of the above proportions is conveyed in British ships frequenting the various foreign ports, and acting, as I have said, as the ocean carriers of the world.

Thus, in the best returns available I find that British shipping conveys the following proportions of the oversea commerce of other countries:—

Italy	44	per cent.
Germany	38	„
Russia	57	„
Norway	18	„
Sweden	27	„
Holland	54	„
United States	60	„
France	(not given)	

The experience of the Suez Canal again tells the same tale, for of the total tonnage passing through that international waterway 66 per cent. is British. This is nearly seven times that of the shipping of the next largest contributor, which is Germany, and nine times that of France.

This vast amount of carrying trade is in British hands, because we can do it cheaply as well as efficiently. I believe that the whole of our commercial fleet is worked at a very narrow margin of average profit, though in the aggregate it forms one of the most important factors in our country's position among the nations of the world.

We are often reminded of how greatly the value of our imports exceeds that of our exports; but we should not forget that the profit on the transport of both goes chiefly to the British nation as shipowners, in addition to the profit which is earned by them in the carriage of merchandise from one foreign port to another.

What an important thing it thus is to the prosperity of this country, not merely that our own ports should be convenient and adequate to all demands, but that our shipbuilders should be able to keep pace with the demands of this huge transport traffic! We find in this connection that we add about half a million of tons of shipping annually to our register, and that we lose about 250,000 tons annually by wreck and by vessels becoming old or obsolete, so that, as a matter of fact, the average annual increment of our mercantile navy for the past twelve years is about a quarter of a million of tons.

The remarkable development within recent years in the cheapness of steam navigation, the improved methods in the building and rigging of sailing ships, and various economic causes, have resulted in a large increase in the average size of ship engaged in oversea voyages with a comparative diminution in the number of the crews of each description of vessel. Greater draught of water is consequently demanded, and, as a better knowledge of shipbuilding has indicated that the beam of ships can be considerably increased without involving greater resistances, we may expect to see ships to increase not only in length and depth, but also in width.

The largest steamer twenty years ago (excepting of course the 'Great Eastern,' which was a magnificent conception, though in advance of her time and its requirements) was, I believe, the 'City of Berlin,' of 5,500 tons burden. Her length was 488 feet, and her draught and beam were 25 feet and 44 feet respectively. At the present time the 'Kaiser Wilhelm der Grosse' is 625 feet long; her beam is 66 feet and her draught is 27 feet, and we know that these dimensions will soon be exceeded.

A modern liner now being built will have a length of 704 feet (or 24 feet longer than the 'Great Eastern') with a beam of 68 feet and a draught of 28½ feet. The great steamers for the transport of cattle are 585 feet long, 64 feet beam, and 30 feet draught and upwards, carrying 14,000 tons of cargo. Some of the large sailing vessels carry over 6,000 tons dead weight and draw 28½ feet. Ships of war, though not so long as liners, have a beam of 75 feet with a draught of 31 feet, and though in the commercial marine we need not perhaps anticipate any great further increase of draught of water, the demand for which is largely governed by what is available in foreign ports or rivers and in the Suez Canal, the fact that men-of-war can, with due regard to economy of propulsion, be built with great width of beam in proportion to length, seems to indicate that we must be prepared in the future for a considerable increase of beam for cargo-carrying vessels.

We have further to note that, owing, no doubt, to the vast improvements of marine steam-engines and boilers realising unlooked-for economy in the combustion of coal, steam vessels are supplanting all but the largest class of sailing vessels as carriers of commerce, almost as rapidly as they did forty or fifty years ago in the conveyance of passengers and as ships of war.

In 1897, out of a total shipping trade (cargoes and ballast) dealt with in ships of all nations at the ports of the United Kingdom, amounting to ninety millions of tons, eighty-one millions of tons, or 90 per cent., were conveyed by steam vessels; whereas, in 1885, out of a total of sixty-four millions of tons, fifty millions of tons, or 78 per cent., were in steamers. If we take, however, the tonnage of cargoes and ballast conveyed to and from her own ports by British ships only, we find that in 1897, out of a total of sixty-four millions of tons, sixty-one millions of tons, or 95 per cent., were in steam vessels; whereas, in 1885, but 85 per cent. of the total tonnage conveyed by British vessels was in steamships.

Of the tonnage of vessels built in the United Kingdom in 1885, 50 per cent. were steamers, but in 1897 the proportion was 86 per cent.; and, to sum up, we find that in the commercial fleet of the United Kingdom and British Possessions, as between 1887 and 1897, sailing ships have decreased 16 per cent. in number and have, in spite of the building of a certain number of exceptionally large vessels, decreased 9 per cent. in average size; while steamers have increased 23 per cent. in number and 16 per cent. in average size. The total sailing tonnage has decreased in the same period by 24 per cent., and the steam tonnage has increased by 36 per cent.

The problems thus confronting us, as results of the increased size of all descriptions of oversea steamships, require much consideration from an engineering point of view, and are further puzzling, and will continue to puzzle, our financial authorities, without whose aid the engineer can do but little.

We ask, Where is all this expansion of requirements to stop, and how far are we justified in extending our view of the wants of the future from the contemplation of the conditions of the present and of what has occurred in the past? This is undoubtedly a difficult question, and he would be a bold man who thought that we had reached finality in the size of ships. Bound up with this consideration are not merely matters of first cost of the accommodation to be provided, but also of the annual expenses in working and maintenance, not only of the docks themselves, but in what is perhaps of more importance—viz. in the preservation of sufficiently deep and wide approaches to them.

Apart from length, depth, and beam, the midship cross-section of modern cargo ships has altered completely of late years, and is now nearly as rectangular in shape as a packing-case, excepting only that at the bilges the sides and floor are joined by a curve of small radius. The keel has almost disappeared, and bilge keels are often added. The result of these alterations of shape in the ordinary hulls of trading ships is that the sills and sides of many locks and entrances are now unsuited to the new form of hulls, and consequently their original power of accommodating vessels is most seriously diminished.

Until lately it was generally considered that locks 600 feet long, 80 feet wide, and 26 feet deep were sufficiently capacious, with some margin for future wants; but I think we must now go further in length and depth, and not improbably to some extent in width. We find that at Liverpool the Dock Board have ordered vestibule basins to act as locks 1,150 feet long and 520 feet wide, with entrances 100 feet wide and 32 feet deep; and somewhat similar dimensions were talked of for the entrance lock of the recently proposed Windsor Dock at Penarth, which was intended to be 1,000 feet long, 100 feet wide, and 34 feet deep at neap tides.

Again, apart from the question of locks and entrances, the older docks themselves are beginning to be found too shallow and too narrow for modern vessels. In docks which are deep enough at spring tides and too shallow at neap tides, and which are opened to the 'tide of the day,' much may be done to improve the depth by systematic pumping, so as to keep the surface always at the level of high water of spring tides. By this expedient, large areas of old docks may be to that extent modernised at the expense, perhaps, of new entrance locks and the annual cost of pumping. This latter yearly outgoing is not an important matter. At Liverpool and Birkenhead 230 acres of nearly obsolete docks have been thus improved at a capital cost of about 96,000*l.* for pumping machinery and an annual expenditure of 6,000*l.* I am executing a similar improvement by pumping in one of the smaller docks on the Thames, and contemplate it on a larger scale at an important dock there, and also at Hull.

The conditions of commerce now require also, in order to realise the necessary economy of transport, the greatest despatch, for demurrage on the large and expensive modern steam vessels is a most serious question. Thus there must now be no waiting for spring tides, or, if possible, for rise of tide on the day of arrival. Every steamer expects to discharge her cargo on to the quay without waiting for much stacking, still less for trucks; and under modern conditions dock work must be got through in one-third of the time which was considered proper ten or twelve years ago. From these reasons larger quays and warehouses, better railway approaches, improved sidings, and better machinery are all necessities, as well as deeper water and better approaches.

These demands have come on us, as I have said, not so much gradually as more or less suddenly, and the call for improved docks is general, and, in my opinion, it will be continuing.

Liverpool last year undertook to spend nearly five millions on such works, and we know of very many important projects at other places. Taking the expenditure within the past decade, and adding to it the authorised expenditure at Liverpool, at the great ports on the Bristol Channel, on the Thames, at Southampton, Hull, Middlesbrough, Hartlepool, Sunderland, the Tyne and its neighbourhood, at Grangemouth, the Fife Ports, at Glasgow, the Ayrshire Ports, the Cumberland and Lancashire Ports, and so round the British coasts to Preston and the docks at Manchester, and apart from the canal, I roughly estimate an expenditure, either made during the past ten years or contemplated, of from 35 to 40 millions.

These are large figures, and we ask from whence will an adequate revenue come? for it is a more or less accepted fact that docks by themselves do not produce more than a very moderate return on their cost, though, of course, there may be exceptions to every rule. Apart from the expenditure which has been undertaken, much remains to be done, and the source of supply of the capital required is a highly important consideration. I venture to think on this point that we should learn to realise that under modern conditions docks should be considered largely in the light of being railway stations for goods and minerals and, in many cases, for passenger traffic. Docks and quays, together with improved approaches from the sea, are, in fact, the means of bringing traffic to the railways (and, to a less degree, to the canals) of a country, and should be looked upon as links in the chain of transport and intercommunication.

They are certainly as necessary adjuncts of a railway, at least in our country and in respect of goods and minerals, as large stations and depôts are in all important towns.

The older view of our Parliament was that docks and railways should be in different hands; but I much question whether this idea should now commend itself. It is difficult, as I have said, for a dock enterprise standing alone to make any considerable return on its cost, and, though it is true that capital can be found under guarantees of an already developed trade by some of the great Dock Trusts, such as at Liverpool or Glasgow, the return is but a modest one, and not such as is likely to tempt capitalists to new ventures in constructing or enlarging many of the docks which stand in need of improvements.

On the other hand, a railway company which gets a fairly long lead for the goods to and from a dock can afford to look at the matter of expenditure on docks with some liberality. We have conspicuous examples of great public benefit being afforded at Southampton and at Hull, where the docks have lately passed from the hands of financially weak companies, dependent only on dock dues, to the ownership of powerful railway companies. Similarly, several of the North-eastern ports besides Hull—the large docks at Grangemouth, Barry, Penarth, Garston, Fleetwood, and elsewhere—are further examples amongst others in which the revenue of railway companies has been spent on dock improvements with a spirit which would be otherwise unattainable. A dock also must necessarily be nowadays almost wholly dependent for its efficient working on the best understanding being maintained with the railway companies for the prompt and adequate provision of land transport, so that in that point of view also the two interests are one and should be recognised as such.

In the consideration of the advisability for concentration of ownership, there remain only the questions of safeguards against unfair treatment of competitive modes of transport, such as canal and road traffic, and provision against any improper results of monopoly of railway access. These, I think, can be provided by Parliamentary enactment, either by insisting on adequate access under proper conditions for all within reach, or, in any case of inadequate facilities being accorded, by authorising the construction of other docks in the hands of competing railway companies or of other aggrieved parties, with in such cases railway privileges. With these safeguards the public could be efficiently protected, and, if this be so, I cannot but think that, *cæteris paribus*, the trading community will be better served by docks directly connected with railway companies than by separate existences and management. On the one hand, I hope that those who administer the great railway undertakings will realise this community of interest, and, on the other, that Parliament will favour intimate financial relations between docks and railways, instead of more or less systematically discouraging such connection. This question is one which is peculiarly interesting here at Bristol, where the docks are in the hands of the Corporation, and where the railway companies carry the traffic, which, but for the docks, would be largely non-existent.

(III.) Leaving now the question of modern docks and shipping, as to which, as I have said, Bristol is interesting to engineers, there are one or two other matters of history which appeal to Section G in this locality. In the first place, Bristol was the birthplace of the Great Western Railway. I. K. Brunel, its engineer, had previously, by public competition, been selected to span the gorge at Clifton by a suspension bridge of the then almost unrivalled span of 702 feet. Again, under the influence of Brunel, Bristol became the home of the pioneers of Transatlantic steamships, and the story of the initiation of the enterprise is thus told in the memoirs of his life. In 1835, at a small convivial meeting of some of the promoters of the Great Western Railway, some one said, 'Our railway to Bristol will be one of the longest in England,' and Brunel exclaimed, 'Why not make it the longest line of communication in the world by connecting it with New York by a line of steamers?' Out of this grew the 'Great Western' steamship, and the history of the enterprise and of its success is too well known, at least here, to require any allusion to the steps by which it was brought about. Suffice it to say that, in spite of much discouragement, the 'Great Western'—of the then unexampled size of two thousand three hundred gross tons, and with engines of unparalleled power—was launched at Bristol in 1837, and ran successful and regular voyages till 1857, when she was broken up.

In Section G there are many who can appreciate the difficulties of such a new departure as the 'Great Western' steamship, even if they had been confined to the design and study of a vessel and engines of unprecedented size; but it is not easy to realise the anxiety and trouble caused by the dictum of a scientist so universally admired as Dr. Lardner, at the meeting of the British Association in this city in 1836, that the whole idea of ocean navigation on voyages as long as from Bristol to New York was at that epoch an abstract impossibility.

In these days of criticism of the past, often involving the rehabilitation of individuals, it is interesting to note that Dr. Lardner's part in condemning beforehand the construction of the 'Great Western' steamship and the ideas on which she was designed has been of late years unduly minimised. It has been said that all Dr. Lardner meant was to express a pious doubt as to the commercial prospects of ocean navigation. I have carefully read the 'Proceedings' of the time, and I am brought to the conclusion that his words and writings will admit of no such interpretation. Dr. Lardner's views, arrived at after calculation and reasoning, were precisely expressed and boldly and honestly enunciated by him. The words of the discussion here appear not to have been preserved; but in the elaborate article in a Quarterly Review in 1837, which is, I believe, admitted as having been written by Dr. Lardner, and as expressing his matured views, he said 'that in proportion as the capacity of a vessel is increased, in the same ratio, or nearly so, must the mechanical power of the engines be enlarged and the consumption of coal augmented.' He based his views that success was impossible on principles which he supposed to be sound, but which were, in fact, assumptions—viz. that the resistance to the progress of a ship varied directly with her capacity, that a certain number of tons of coal were required in 1836 per horse-power for the voyage across the Atlantic, and that, this being so, enough fuel could not be carried in a ship, however large she might be made.

Brunel, on the other hand, contended that Dr. Lardner's views were fundamentally erroneous; for that, whereas the capacity of a ship increased in the ratio of the cube of her dimensions, the resistance to her progress varied more nearly as the square. Thus, by adopting a proper length, beam, and draught, a ship would not only carry coal for the journey to New York, but be commercially successful in respect of cargo and passengers.

It is interesting to note that 9 lbs. of coal per indicated horse-power per hour (as compared with our present $1\frac{1}{2}$ to 2 lbs.) was the approximate coal consumption which was more or less accepted by both sides in the controversies of 1836 and 1837.

We know now that the resistances encountered by a ship are not merely dependent on her dimensions, but comprise wave-making at various speeds, bringing form and proportion of dimensions largely into the necessary calculations; but I want to point out that the line of divergence of the different views of Lardner and Brunel was sufficiently precise and quite crucial. It is true that Dr. Lardner, in later criticisms of 1837, retreated somewhat from his position of 1836, introducing more of the commercial aspect of the case and stating that no steam vessel could make profitable voyages across the Atlantic, at least until marine engines were immensely improved; but, even so, it seems clear that the fundamental matter at issue in 1836 and 1837, the period of Dr. Lardner's active criticism, was the question of the resistances increasing in the same ratio as the capacity. The results of these *ex cathedrâ* statements by Dr. Lardner about the 'Great Western,' then in process of being built, must have caused great anxiety to the promoters and much preliminary distrust of the ship on the part of the public. They were, unquestionably, honestly arrived at, however much they were due to reasoning on unascertained premises, and this latter is the reason for my venturing now to refer once more to them. As a matter of fact, the ship started from Bristol in 1838, and arrived at New York in fourteen days with 200 tons of coal in her bunkers.

Let me remind you of another somewhat similar instance of the way in which the anxieties of engineers have been unnecessarily increased and public alarm gratuitously, though honestly, aroused. When the designs of the Forth Bridge—of which the nation, and indeed the world, is proud—had been adopted both by the railway companies who were to find the capital and by Parliament, a most distinguished man of science—the then Astronomer Royal—came to the conclusion that the engineers had neglected certain laws which he enunciated respecting the resisting power of long struts to buckling, and that the bridge ought not to be constructed, as he considered that, to use his own words, 'we may reasonably expect the destruction of the Forth Bridge in a lighter gale than that which destroyed the Tay Bridge.' All this was stated, no doubt, from a strong view of public duty, in a letter to a public newspaper, though subsequently and frankly withdrawn. If the bases of his calculations were right, the conclusion might have been correct; but the fact was that there was no foundation worthy of the name for the reasoning. Again, another distinguished mathematician publicly criticised the Forth Bridge with equal vigour, basing his views that it was fundamentally incorrect on another set of equally erroneous assumptions, maintaining again that it should not be permitted, because he proved by reasoning on those assumptions that it must be absolutely unsafe.

Once more, in shipbuilding: until Mr. William Froude, some years prior to 1875, made his experiments by means of models on the highly difficult and otherwise almost insoluble causes of the retardation of ships and their behaviour in waves, beginning at the beginning, taking nothing for granted, and eliminating all elements of possible errors, little or nothing was known of the laws governing these questions. Laws had been laid down by high authorities as to the causes of retardation of ships, many of which, in fact, were not true, while some of the assigned causes were non-existent and some real causes were unrecognised. Mr. Froude was told that little or no information could be learnt from experiments on models which would be applicable to full-sized ships, and that ships must continue to be designed and engines built on data which, scientifically speaking, were assumptions. The outcome has been that Mr. Froude's *à priori* depreciated experiments with models have solved most of the questions relating to that branch of naval architecture; and at the present time every ship in the Royal Navy, and not a few in the merchant service, are designed in accordance with the data so gained.

Another example of hasty generalisation occurs to me, and that is on the important question of wind pressure. Tredgold, who undoubtedly was one of the soundest of engineers, laid down in 1840 that a pressure of 40 lbs. per square foot should be provided for; reasoning, no doubt, from the fact that such a pressure had in this country been registered on a wind gauge of a square foot or less in area. As a consequence, he assumed that the same force could be exerted by the wind on areas of any dimensions. Thus, roofs and bridges, wherever any calculations of wind pressure were, in fact, made, were designed for a pressure of 40 lbs. per square foot of the whole exposed surface; and under the alarm caused by the fall of the Tay Bridge in 1879, the piers of which were not, probably, strong enough to resist a horizontal pressure of one-fifth of such an amount, a further general assumption was made, and railway bridges throughout the kingdom were ordered by the Board of Trade in 1880, acting no doubt on expert advice, to be in future designed, and are designed to this day, to resist 56 lbs. of horizontal wind pressure on the whole exposed area with the ordinary factors of safety for the materials employed, as if such horizontal strain were a working load.

It had, for a long time previously to this order of Government being issued, been suspected that these small-gauge experiments were untrustworthy, and subsequent experiments at the Forth Bridge on two wind gauges of 300 square feet and of 1½ square feet respectively indicated that with an increase of area the unit of pressure fell off in a very marked degree. Under the same conditions of wind and exposure the larger gauge registered a pressure 38·7 per cent. less per square foot than the smaller gauge. I have been able to carry experiments further at the Tower Bridge by observing the pressure on the surface of the bascules of the bridge as evidenced by the power exerted by the actuating engines. In this case we have a wind gauge of some 5,000 feet in area, and it has been shown that, while small anemometers placed on the fixed parts of the bridge adjoining the bascules register from 6 to 9 lbs. per square foot, the wind pressure on the bascules is only from 1 to 1½ lb. per square foot.

It is difficult to imagine the amount of money which has been expended in provision against wind strains of 56 lbs. per square foot on large areas in consequence of hurried generalisation from insufficient data. I know something of what this provision for wind cost at the Tower Bridge, and I do not wish to mention it; but if the public had been told that the dictum of experts, arrived at however hastily in 1880, was to be set aside in the construction of that bridge, all confidence would have been beforehand destroyed in it, and I suppose no Committee of Parliament would have passed the Act.

I have mentioned these matters, which could be added to by many similar instances in other branches of applied science, not for the sake of reviving old controversies or of throwing a stone at highly distinguished men, honoured in their lifetime and honoured in their memory, nor for the sake of criticising more modern scientists or a Government Department. Still less do I wish to question the necessity and value of mathematical calculations as applied to the daily work of engineering science, but I recall the circumstances for the purpose of once more pointing out the extreme value of experimental research and of bespeaking the utmost caution against our being tempted to lay down laws based on unascertained data. We know the tendency there has been at all times to generalise and to seek refuge in formulæ, and we cannot but know that it is not at an end now. We ought to recognise and remember how few physical questions had been exhaustively examined sixty years ago, and may I say how comparatively few have even now been fundamentally dealt with by experiment under true scientific conditions? The investigation of physical facts under all the various conditions which confront an engineer requires much care, intelligence, time, and last, not least, not a little money. In urging the vital necessity of investigations, I am sure that I shall not be understood as decrying the value of the exact analysis of mathematics, but we must be quite sure that the premises are right before we set to work to reason upon them. We should, then, exert all our influence against rules or calculations based merely on hypothesis, and not be content with assumptions when facts can be ascertained, even if such ascertainment be laborious and costly. In a word, let us follow sound inductive science, as distinguished from generalisations; for 'Great is truth and mighty above all things.'

In connection with this subject, I may congratulate the Association generally, and this Section in particular, that there is now more hope for experimental science and some endowment of research in this country than at any former time. The vital necessity of further work in these directions has long been recognised by men of science, and was notably urged by Professor Oliver Lodge. Last year, in no small degree owing to the exertions of Sir Douglas Galton, K.C.B., who presided over the British Association in 1895, and brought the question very prominently forward in his inaugural address on that occasion, a highly influential deputation waited on the Premier to urge that England should have a Public Physical Laboratory, at which facts could be arrived at, constants determined, and instruments standardised. The importance of the questions which could be determined at such an institution in their influence on the trade and prosperity of the country, independently of the advancement of purely scientific knowledge, cannot well be exaggerated.

Our Government, while somewhat limiting the scope of the inquiry, appointed a small Committee to examine and report on this highly important subject. It is no breach of confidence to say that the Committee, after taking much evidence, visiting a similar and highly successful institution on the Continent, and studying the question in all its bearings, were convinced of the great public benefits which may be expected from such an institution, and have unanimously reported in favour of its establishment.

I feel sure that we shall all earnestly hope that Government will carry out the views of the Committee, and I venture to suggest that each of us should use what influence he may have to induce the Chancellor of the Exchequer to find adequate funds for an institution which may be of the greatest benefit not merely to scientific research, but to the commerce of these islands, threatened as it is on all sides by foreign competition of the most vigorous description—a competition which is supported by every weapon which the science of other lands can forge for use in the struggle. It being acknowledged that our own work in life is to deal with physical facts and apply them for the use of our fellow-men, we may have good hopes that at such an institution as I have indicated, directed, as it no doubt will be, by the highest scientific superintendence, we shall be able, at least far better than at present, to have a sound knowledge of many facts which are obscure, and to deal with the many new conditions under which the applied science of the future will have to be carried on.

Those who know most of the problems of Nature feel the more strongly how much remains which is unknown, and realise how completely those who teach require throughout their lives to be always learners. Let each of us, then, in our special walk of life, seeking for further enlightenment on the various problems of our work and in the application of that science which we love, humbly recognise that

> 'All Nature is but art, unknown to thee;
> All Chance, direction which thou canst not see;
> All Discord, harmony not understood.'

The following Papers were read:—

1. *New Works at Barry Docks.* *By* R. C. H. Davison.

2. *Conditions necessary for the Successful Treatment of Sewage by Bacteria.* *By* W. J. Dibdin.

FRIDAY, SEPTEMBER 9.

The following Papers were read:—

1. *Description of an old Newcomen Engine at Long Ashton, near Bristol.*
By W. H. Pearson, *M.Inst.C.E.*

2. *Factitious Airs.* *By* Sir Frederick Bramwell, Bart., *F.R.S.*

3. *The Mechanical and Economic Problems of the Coal Question.*
By T. Forster Brown, *M.Inst.C.E.*—See Reports, p. 611.

4. *The Hydraulic System of Jointing of Tubes on Tubular Bodies.*
By Claude Johnson, *M.Inst.C.E.*, *M.Inst.E.E.*

The practical utility of this system has only been demonstrated during this year. The inventor of the process, Mr. C. T. Crowden, constructed apparatus in 1896, which, being actuated by hand power, was experimental only. In 1897 the funds were obtained for the construction of steam machinery from the author's design; and in January of this year a machine, which is known as a hydro-compressor, was completed and was found to work successfully.

In making cycle frames it was found that every joint in a frame (usually about ten in number) could easily be made in seven or eight minutes—this time included the assembling of all the tubes, lugs, &c., which constitute a cycle frame, in the machine and the taking out of the completed frame—after the operation of applying the water pressure. The hydraulic pressures applied to the forming of the joints varied from three to nine tons per square inch. All the joints in a cycle frame are made at the same moment, and, as no heat is employed, the frame when removed from the jig or mould is perfectly true and requires no setting. All the laborious cleaning off, sand-blasting, and the consequent weakening of the tubes by filing of the metal are entirely avoided, so also is the loss of strength in the tubes due to the tempering of the metal.

In the *brazing process* the tubes are first connected to the iron sockets or lugs, which form the connecting pieces at all the angles of the frame, by means of small screws inserted at the sides of the lugs. The frame is then placed on a hearth of red-hot coke, is heated to a bright-red heat by the application of a 'Bunsen' gas jet, and the brass solder is run into all the joints in turn, a suitable flux being employed to effect the union of the metals. When the frame has passed through this ordeal the brazing material has spread over the external surface of the tubes and lugs, and has to be subjected to various 'cleaning-off' processes—viz., sand-blasting, filing, &c. The former is very injurious to the health of the workmen, and the latter is necessarily very weakening to the tubes. The frame is also very much twisted by the heat, and the steel tubes themselves are much weakened, especially at that part where most strength is needed—*i.e.*, at their junction with the lugs, this portion being practically brought to the condition of cast metal, and the mechanical hardness due to drawing the tubes is entirely lost. The scale, too, which is so difficult to clean off, it must be remembered, is formed by oxidisation, at the expense of the tube.

With the *hydraulic process* the time occupied in making a frame is entirely dependent upon the rapidity with which frames can be placed in and withdrawn from the jig. This device, it must be explained, is a heavy cast-iron mould in two parts, in which the tubes of the cycle frame and the lugs are placed. After these parts are closed, water, under a pressure of from five to seven tons *per square inch*, is applied to the interior of the cycle frame, and by this means the tubes, where they lie within the lugs, are so expanded as to become indissolubly united to them. The interior surface of the lugs is spirally grooved in reverse directions, so that the tubes when expanded are locked therein, and cannot be moved in the direction of their axes or be unscrewed. The closing of the mould or jig which, contains the frame is effected by the action of the piston of a steam cylinder, which, through the medium of a system of toggle joints, exercises the necessary pressure; the mould is then automatically locked. A second stroke of the piston actuates the plunger of a hydraulic intensifier which gives the pressure required for making all the joints instantaneously. The press is then opened, and the cycle frame, completely jointed, perfectly true to shape, and without twist or weakness of any kind, is removed.

Drawings and samples of the work performed by this machine were exhibited.

5. *Description of an Instrument for Measuring small Torsional Strains*

By E. G. Coker.

SATURDAY, SEPTEMBER 10.

The Section did not meet.

MONDAY, SEPTEMBER 12.

The following Papers were read:—

1. *Electric Power in Workshops. By* A. SIEMENS, *M.Inst.C.E.*

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2. *The Application of the Electric Motor to small Industrial Purposes and its Effects on Trade and on the Community Generally. By* ALFRED H. GIBBINGS, *M.I.E.E., President of the Municipal Electrical Association; City Electrical Engineer, Bradford.*

The electric motor has paramount advantages over any other method of utilising potential energy, but its use is restricted at present to a few large special trades and manufactures. Gradually, however, these advantages are becoming known and appreciated by smaller tradesmen and handicraftsmen.

It is in limited use, for instance, among such divers trades as aërated bread makers, bag makers, bookbinders, carpenters, cutlers, engineering workshops, fans for ventilating and other purposes, lifts, lithographers, presses, printers, saw mills, &c.

The advantages of driving electrically in some of these cases are of a very distinctive character. Boiler makers can drill rivet holes more accurately and economically. In letterpress and lithographic printing the extremely steady and even motion consequent on the rotary action of the electric motor is an important feature. Speaking generally, great advantages for all industries are secured by the possibility of placing the motor close up to its work, and thus dispensing with long lines of shafting and countershafting, which in one actual test were found to absorb 56 per cent. of the actual power generated. The motor can be instantaneously switched 'on' and 'off,' which, of course, effects great economy in use. Also the resultant in horse-power hours or Board of Trade units taken on the average of the varying loads is an important characteristic of the electric motor due to its high efficiency, but it is a most difficult thing to get power users to see it. A great hindrance to a more extensive use of the electric motor among small tradesmen is the want of capital to buy motors, and the want of confidence. The owners of electrical supply undertakings should therefore make it a part of their business to purchase good reliable motors and let them out on hire. This scheme was inaugurated in Bradford at the end of 1896, and has had most successful results. In the two months of 1896 seven were hired, in 1897 thirty-nine, in 1898 (six months only) thirty-one. The number of Board of Trade units sold in 1897 was 117,176, in 1898 it is likely to be 180,000, or an increase of 53 per cent. Other cities and towns do not yet make equally satisfactory returns. The value of the electric motor as a factor in reducing the working costs of any electrical supply works is well known.

The electric motor as a machine is so adaptable and economical as applied to small trades and industries that it may well help them to compete with larger firms; it may lead to the revival of some industries and the return of others which have gone abroad, such as toy making. Hygienically considered, it gives off no deleterious gases, and displaces the boiler and smoky chimney.

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3. *Electric Power and its Application on the Three-phase System to the Bristol Waggon and Carriage Works. By* W. GEIPEL, *M.Inst.C.E.*

Hitherto power has been transmitted either by long steam-pipes to scattered engines, or from one large engine by gearing and shafting.

On the former system are driven shipyards, rolling mills, engineers' works, &c., where the total consumption of steam may be as much as ten times that of an economical engine. The latter system is used in such places as weaving and spinning mills, where the engine may be highly economical and yet as little as 1 per cent. of its power applied to the fabric or cotton itself.

Electric power is advantageous in both, but more particularly in the former class of works. The importance of this subject is emphasised, seeing that one firm may use as much energy as lights an average provincial town.

An instance of the wastefulness of driving by scattered engines is the old plant, now replaced by electric power, at Messrs. T. Richardson, Son, & Co.'s, of West Hartlepool. Here there were 31 engines of 94 horse-power downwards, using an average of 51 lbs. of steam per I.H.P. hour, generated in 8 main and 23 auxiliary boilers. Now there are two main boilers and two steam alternators, with one 'stand by.' Again, at the Bristol Waggon Works, 5 Lancashire boilers, and 5 engines are being replaced by 1 Lancaster boiler, and 1 engine.

Referring to the different sources of loss in the use of scattered engines, a serious one is that due to condensation in long steam pipes. This loss is the equivalent of one half-ton of coal for every square foot of bare pipe continually under steam per annum, and for lagged pipe it may be one-fourth to one-sixth of a ton. At Messrs. Richardson's there was 1,200 feet of steam pipe; at the Bristol Waggon Works 750 feet of pipe is being replaced by 30 feet.

The present system is wasteful, not only in fuel, but in water and stores, and in labour in firing boilers and attending engines.

The loss in shafting and gearing was 25 per cent. to 70 per cent.—average 43 per cent.—at Messrs. Richardson's; about 50 per cent. at Messrs. Furness, Westgarth, & Co.'s, of Middlesborough; and from 37 per cent. to 75 per cent.—average 50 per cent.—at the Bristol Waggon Works.

The loss in electric transmission, including dynamo, conductors, and motors, need not exceed 24 per cent. But the loss in conductors and motors occurs only during use, and not when the motors are standing; on the other hand, the loss in the shafting is continuous whether the machines are standing or not. This fact seriously adds to the comparative inefficiency of transmission by shafting.

Small engines are generally badly governed or overloaded, both of which facts give rise to variations in the speed of the tools and a consequent reduction of output. Electric motors run at a constant speed, even with a considerable excess of the full load, and effect an increased output. At the Bristol Waggon Works one of the engines is pulled up to one-half its normal speed when a large tool is thrown on. Electric power gives greater flexibility in providing for extension—an additional motor is so easily added—while with separate engines there is a difficulty.

The Old Steam Plant at the Bristol Waggon Works.

There are 5 horizontal engines, 3 being antiquated and having slow-speed throttle-governors, the valves being set to cut off as late as 83 per cent. of the stroke, so that hardly any expansion is obtained. Two of the engines are modern, though using low-pressure steam with long steam pipes. Steam is generated in 5 Lancashire boilers.

The steam consumption, calculated from the diagrams, varied from 96 lbs. to 32 lbs. per I.H.P. hour. This excluded loss in cylinders and pipe condensation and leakage past the piston. One engine is very inefficient, and there was found to be excessive leakage on removing the cylinder cover. Probably 25 per cent. would be a small allowance for this and cylinder condensation, which, together with the calculated loss in 158 feet of steam pipe, shows the actual consumption to be nearly 150 lbs. of steam per I.H.P. hour in this case.

The loss of steam pressure between boiler and cylinder was sometimes 40 per cent., and the annual loss by condensation in steam pipes was 2,575,000 lbs., the equivalent of 154 tons of fuel.

The total fuel consumption is about 2,500 tons per annum. The average load on all engines is 254 I.H.P., the working hours per annum about 2,800, and the total energy about 710,000 I.H.P. hours per annum. The total steam consumption, allowing 10 per cent. for leakage and cylinder condensation and the above loss in pipes, is 41,625,000 lbs., and the evaporation about 7·5 lbs. of water per lb. of fuel. The average consumption of fuel is 7·9 lbs. per I.H.P. hour.

The diagrams obtained show the maximum load to be 354 I.H.P., the normal load 254 I.H.P., and light load 207 I.H.P. Of this there is lost in engine friction 45 H.P. and in shafting 88 H.P. = 133 H.P. The average power used by the tools is 121 H.P.—that is, 48 per cent. of the normal power of the engines. In the case of two of the engines the tools used only 25 per cent., 75 per cent. being lost.

Power Required for Electric Driving.

Ten motors will be used, ranging from 65 to 2 H.P., driving the shafting near to where the work is taken off. Considerable shafting will be discarded, and the total power developed by the motors will be 76 H.P. less than the present engine I.H.P.

The new boiler will evaporate 9 lbs. of water per lb. of fuel, while the engine will use 16 lbs. of steam per I.H.P. hour. Allowing for contingencies, the fuel per I.H.P. hour will be 1·9 to 2 lbs., just one-fourth of that used at present.

The efficiency of the electric system, taking the ratio of the power at the motor pully to the I.H.P. of the generating engine, is 69 per cent., and 258 I.H.P. will be required as an average. The I.H.P. is practically the same as before, but the saving by the use of an economical engine close to its boiler represents, for reasons as before stated, 1,000*l.* per annum.

The three-phase system was adopted after full consideration, because of its superior mechanical merits and the absence of commutators and brushes, which are troublesome adjuncts of the direct-current system.

The new plant will consist of one Lancashire boiler, with Bennis automatic stoker and damper regulator, a 96-tube Green's economiser, a 400 I.H.P. horizontal compound surface-condensing engine, an Edward's air pump, a 6-inch centrifugal circulating pump, and a Klein cooling tower for the condensing water.

There will be one 275 B.H.P. Brown-Boveri three-phase generator and 10 motors from 65 H.P. downwards, all supplied by Messrs. T. Richardson & Sons, of Hartlepool. For lighting the works there will be 750 glow and 22 arc lamps grouped on the three phases and run at 110 volts. The motors will be arranged for 190 volts effective. The lower lighting voltage enables the use of more efficient lamps. The wiring will be protected by hard wood casing throughout, and the whole of the work is being carried out by the firm with which the author is associated.

4. *The Electric Lighting System at Bristol, with Special Reference to Auxiliary Plant. By* H. FARADAY PROCTOR.

5. *Electric Traction by Surface Contacts.*
By Professor SILVANUS P. THOMPSON, *F.R.S.* and MILES WALKER.

TUESDAY, SEPTEMBER 13.

The following Papers were read:—

1. *Schemes for the Improvement of the Waterway between the Bristol Channel and the Birmingham District. By* E. D. MARTEN, *M.A., M.Inst.C.E.*

The trunk waterway consists of the tidal Severn estuary for 20 miles from Bristol Avon to Sharpness Docks, thence of the Gloucester and Berkeley Ship Canal for 16 miles to Gloucester, and of the canalised river Severn for 42 miles from Gloucester to Stourport.

It is connected with the Birmingham district by the Worcester and Birmingham Canal and the Staffordshire and Worcestershire Canal. The former leaves the Severn at Worcester, 30 miles above Gloucester; is 30 miles long, has a rise of 418 feet, and serves the southern portion of the district. The latter leaves the Severn at Stourport, and thence it is 27 miles with a rise of 419 feet to Wolverhampton, at the northern end of the district.

Both canals are connected with the Birmingham Canal Navigation, which intersects every part of the district. All three canals are narrow-boat canals accommodating horse-hauled vessels 70 feet long and 7 feet in beam and carrying 25 to 35 tons.

On the Severn a system of steam tugs is maintained, and vessels carrying 150 tons navigate it; but it is capable of accommodating much larger craft.

Vessels engaged in the Continental trade use the docks at Gloucester and Sharpness, and Atlantic liners those at Bristol and other Channel ports, and goods intended for the latter require transhipment at some point after leaving the narrow canal and before passing into the estuary.

The following improvement schemes have been proposed from time to time:—

Mr. G. W. Keeling, Consulting Engineer to the Sharpness Docks Company, proposed to improve the Worcester and Birmingham Canal, increasing its width from 30 feet to 66 feet and its depth from 4½ feet to 9 feet, and with locks large enough to pass two vessels, each 100 feet long and 18 feet in beam, with a carrying capacity of from 200 to 300 tons.

A group of 36 locks, with an aggregate rise of 255 feet, was to be replaced by an incline upon the Monkland principle.

His estimate of the cost of the work was 600,000*l.*, 200,000*l.* of which was for altering tunnels.

The author's scheme was for an improvement of the Staffordshire and Worcestershire Canal: this he proposed to widen to 60 feet and deepen to 7 feet, mainly by raising the level of the waterway, and the means by which this could be done were explained.

By substituting inclines for groups of locks the number of pounds was to be reduced from 31 to 11.

For the incline a modification of the Monkland principle was proposed, its leading feature being that the caisson carrying the vessel would travel up the incline sideways instead of longitudinally, thus getting rid of oscillation. The improved canal would accommodate the same class of vessel, which could with slight alteration to some of the Severn locks at present navigate to Stourport, and the carrying capacity of which varies from 25 tons for a mere barge to 150 tons for a fully equipped coasting steamer.

The estimated cost of the scheme was 360,000*l.*

The depth of water at Sharpness at neap tides is limited to 15 feet, and Mr. Keeling prepared a scheme to make a new entrance at Sheperdine, 5½ miles lower down the estuary, where 8 feet more water could be obtained. This entrance was to be connected with Sharpness Docks by a ship canal, so that liners might enter the docks at every tide.

These works, combined with improvements to the canals, would greatly cheapen transport, as goods could be taken in steam-tugged trains of canal boats without transhipment between manufacturer's wharf and the side of the liner.

There would be four distinct elements of economy—namely, the steam-tugged train, the non-transhipment, the saving in time resulting from the substitution of inclines for locks, and the fact that the liner would be brought 20 miles nearer the Birmingham district.

The estimated cost of the Sheperdine scheme is a little over 300,000*l.*

Vessels of 800 (and in some cases 1,200) tons register trade between Gloucester and Continental ports *viâ* the Ship Canal, which has a navigable depth of about 15 feet.

The Severn for 30 miles from Gloucester to Worcester has a minimum depth of 10 feet; and the problem of increasing this to 15 feet, and so making Worcester a port of equal importance with Gloucester, has always been attractive, particularly as there are only two changes of level.

It would involve the dredging and disposal of 1,500,000 cubic yards of material, new locks at Gloucester and Tewkesbury, a subsidiary entrance at Gloucester, and a transhipping basin at Worcester; whilst the channel at Gloucester would require to be widened and straightened and three bridges converted into opening bridges.

The author estimated that the cost would be considerably under 500,000*l.*

A more modest scheme is to convert the Westgate Bridge at Gloucester into an opening bridge, and so allow of ordinary 300-ton coasting vessels trading to Worcester. The estimate for this and certain subsidiary works was 20,000*l.*

In conclusion, the author expressed belief that the improvements would render possible a great reduction in cost of transport, but considered that there was no prospect of their being carried out unless the local authorities interested would undertake them.

2. *On the Welsh Methods of Shipping Coal. By* Professor J. Ryan.

The author described the arrangements for loading coal adopted at the Alexandra Dock, Newport, at the Bute and Roath Docks, Cardiff, at Penarth, and at Barry.

The chief methods discussed were:—

The *Newport* low-level system, in which the full waggons are received at quay-level, raised by hydraulic elevators to the discharging height, and finally dismissed as 'empties' along an upper stage or viaduct. This method has been followed at the Alexandra Dock, Hull, and elsewhere.

The *Cardiff* low-level system adopted at certain tips at Barry, Roath, &c., where the waggons are received and dismissed at the quay-level, being elevated for discharge by an hydraulic hoist.

The *Barry* high-level system, where the waggons are received and dismissed along different lines on the same elevated staging or viaduct, the waggons being manipulated for discharge by the hydraulic machinery of the tip.

The *Penarth* system, similar to the above, except in the details of the arrangement of the railway lines.

The *Roath Dock* system of loading by Lewis-Hunter cranes, by which each waggon-load of coal is separately lifted in a box and deposited in the hold of a steamer, with a minimum of breakage.

These systems were discussed on the score of economy, of efficiency, and of despatch.

Modifications of these and certain other systems that have been used elsewhere were referred to, and compared with the foregoing.

In the matter of speed in loading, the chief systems are all capable of tipping coal much faster than it can be trimmed in the hold, so that it is only a 'self-trimming' steamer which can tax the capabilities of the tip or crane.

Some instances of rapid despatch were quoted, amongst others:—

The s.s. 'Algoa,' which was loaded in the Alexandra Dock at Newport in 1896, when 11,671½ tons were shipped in 36¾ working hours; that is, at an average rate of 317 tons per working hour, and this maintained for so many hours.

The s.s. 'Samoa,' which was loaded at Roath Dock in 1893, by Lewis-Hunter cranes, receiving 9,234 tons in 28 working hours, this being at the rate of nearly 330 tons per working hour. Higher rates have of course been attained in shorter periods.

At Barry Dock over 490 tons was delivered to the s.s. 'Harbury' in one hour at a single hoist. In 1896 the s.s. 'Ocean,' having been loaded at Barry with 1,900 tons of coal, left on the same tide she entered with. In October last the s.s. 'Harbury' took in 2,467 tons 8 cwt. of coal at Barry between 2.40 P.M. and 7.55 P.M. on the one day, the average rate of loading being therefore in this case nearly 470 tons per hour.

3. *A New Instrument for Drawing Envelopes, and its Application to the Teeth of Wheels and for other Purposes.* *By* Professor H. S. HELE-SHAW, *LL.D., M.Inst.C.E.*—See Reports, p. 619.

4. *Hydraulic Power Transmission by Compressed Air.*
By WILLIAM GEORGE WALKER, *A.M.I.C.E., M.I.M.E.*

The air is compressed by the direct action of the falling water without the aid of moving machinery.

The compressor consists essentially of a head tank, a vertical down-flow pipe, and a separating tank placed at the base of the down-flow pipe. The water may be conveyed to the head tank by means of an open flume or pipe; water entering the down-flow pipe passes the ends of a number of small air pipes, from which air is drawn in the form of small uniform globules, which, becoming entangled in the descending water, are carried down to the air tank, where separation takes place, the air rising to the top of the tank, and the water flowing out at the bottom and up again outside the down-flow pipe to the tail race; the difference in height of the tail race and pipe to head tank gives the available head of water. The globules of air are uniformly compressed at constant temperature during their downward path, the temperature of the water remaining practically constant. The amount of compression of the air depends solely on the length of the down-pipe being independent of available water-fall.

A machine has been erected at Magog, Quebec, a short distance from Montreal, to drive the printing machinery of the Dominion Cotton Mills Company. It has now been in operation over twelve months, running continuously night and day, delivering dry compressed air, with an invariable pressure of 52 lbs. per square inch. It provides power for six printing machines, each of which is driven by a pair of engines with 8-inch by 12-inch cylinders. The cotton mill proper uses water-power, while the printing machines were formerly driven by steam, as printing operations necessitate a very steady power and great variations in speed, the engines varying from 20 to 300 revolutions per minute. Each has its own engine, and in this case the air simply replaced steam, the same engines being used without any modifications.

The depth of the shaft is 128 feet, its size 6 feet by 10 feet, the down-flow pipe is 3 feet 8 inches in diameter, the inverted tank at the bottom of the shaft is 17 feet by 18 feet. The penstock or in-flow pipe is 5 feet 6 inches in diameter, and in the head-piece there are 30 air pipes, each 2 inches in diameter, and each having 32 air inlets at their base, making a total of 960 air inlets. Through these the air mixes with the down-flowing water, thus subdividing the air into an innumerable number of small bubbles. The available working waterhead is 21 feet. By a series of actual tests made by Professor McLeod, of McGill University, it was shown that this plant gave an efficiency of 62 per cent. of the actual horse-power of the water in dry cold air.

This efficiency is secured notwithstanding that 20 per cent. of the air is lost by insufficient separation, owing to the separating tank being a little too small, a feature which may obviously be guarded against in future, so that an efficiency of 75 per cent. is considered as easily obtainable. The actual cost of installation of such a plant is about 10*l*. per horse-power, although much depends on local conditions, the price of labour, material, &c. The cost of sinking the shaft is the principal item, so that larger plants can be installed at a much lower rate per horse-power than small ones.

5. *Combined Electric Lighting and Power Plant for Docks and Harbours.*
By J. G. W. ALDRIDGE.

The introduction and development of hydraulic machinery by Armstrong resulted in the equipment of almost every dock and harbour in the world with hydraulic plant, and this system has been applied to almost every conceivable machine. Until recently, however, the lighting of such places was entirely done by gas, and whilst the hydraulic plant has become more efficient, especially for regular work, gas lighting has proved totally inadequate, and, therefore, electric lighting is now superseding the gas. This, however, necessitates the putting down of two separate sets of machinery, one for hydraulic, the other for electric work, and it is obvious that there must be a certain amount of spare power for each set of machinery, and, moreover, for at least some portion of the twenty-four hours each plant must be at a standstill. The time has now arrived when electric machinery has so far developed that one generating station may be used for all purposes, the most notable instance being that of Copenhagen, Denmark.

The author gives particulars of this installation, and also those at Rotterdam and Southampton Docks and Harbour, with which he is associated, and indicates the direction in which dock and harbour authorities will find the greater economy for combined light and power plant.

The paper was illustrated by diagrams and also lantern slides.

6. *Electric Canal Haulage.* *By* A. H. ALLEN, *A.Inst.E.E.*

Practically the whole of the goods traffic in this country, even up to the year 1825, was carried on canals, of which nearly 3,000 miles had been constructed, and at an immense cost. In this year, 1825—which may be considered the zenith of the prosperity of the canal traffic industry—the Birmingham Canal yielded a revenue of cent. per cent., and one of the Manchester canals paid in dividends every second year a sum equal to the total original outlay.

Since then our once splendid canals—the heritage of the seventeenth century—have, in a great measure, become useless by neglect, and constitute, in comparison with the superb canal systems of Germany, France, and Belgium, a picture far from creditable to ourselves.

Unfortunately, the methods of haulage on our canals in use a hundred years ago are still common; horse traction is still relied upon. On some of our canals steam tug-boats have been adopted with some measure of success, but there are many objections to this innovation; one is the cost of energy in effecting a given tonnage haulage.

The author maintains that by the use of electricity canal traction can be effected in a way that will elevate the method of goods transport to the level of electric railway traction.

An attempt is now made to provide an economic and efficient canal haulage method that can be applied without interfering with existing horse traction, or in such a way that the displacement of the horse system (if desired) can be effected gradually.

The system, which is shortly to be tested on one of our great Northern canals, has been submitted to the critical examination of our most eminent canal experts, and it is admitted that it shows promise of satisfying the numerous and difficult conditions of canal traction.

In the new system, which it is estimated will reduce the freight traffic on canals by 60 per cent., there will not be any loss of the power which will be generated in gas power electric energy generating stations, beyond the trivial one involved in electric transmission. Screw propulsion involves a loss by slip effect of 50 to 60 per cent., but the haulage system involves no loss.

The following is a concise summary of the advantages that are claimed to be possessed by the Canal Electric Haulage System, a scale model of which demonstrates its application to a difficult section of a canal:—

It is proposed to employ the Teslaic alternating system of electric power.

The system will also provide an electric capstan, and light electrically the path, as well as the boats.

The new system claims to possess, and is unique in this respect, the following all important advantages:—

1. It will not interfere with the present horse haulage system.
2. The present boats will not be required to be altered.
3. Smaller boats with less draught can be employed, so that increased speeds can be obtained without producing an excessive and objectionable flush of water.
4. It will be applicable to canals traversing tunnels.
5. No more liability to break down than with ordinary haulage on railways.
6. Suitable for the passage of vessels through the locks as in the present system.
7. Is controllable from the boat, and does not absolutely require the driver associated with horse haulage.
8. The same electric transmission conductors can provide crane and other power for the warehouses and locks and electric light all along the canal.
9. It is much less costly to work than the present horse haulage system.
10. By placing the motors in tandem, or in series, several boats can be hauled along together.
11. The system can be worked with great advantage both by day and by night.

7. *On the Pacific Cable.* *By* CHARLES BRIGHT, *F.R.S.E.*, *A.M.Inst.C.E.*

The author endeavoured to show that there were no insurmountable engineering or electrical difficulties to prevent the realisation of a Pacific cable. He pointed out that the maximum depth to be contended with was but little in excess of that of existing cables, and that our present knowledge of the bottom of the ocean was sufficient for deciding in favour of a particular route. The portion which requires further survey is that between the Fiji Islands and Australia and New Zealand.

The question of the most suitable type of cable was then considered. It must be easy to lay, durable, and capable of being picked up. The author recommends a close-sheathed cable, with the iron wires more or less firmly butting against one another. Each wire should be separately coated with preservative compound and covered with a thin cotton tape.

The strength, pliability, &c., of cables was then discussed. The author has previously suggested that a flexible riband sheathing of aluminium bronze might with advantage be adopted instead of iron wires, thereby enormously reducing the weight, and imparting freedom from corrosion. The riband form is preferred on account of the increased flexibility thereby ensured in a large cable. It is on these grounds, moreover, that the metal tape is not allowed to overlap, or even to meet. Again, such a taping could, under no circumstances, damage the core under tension or pressure.

For paying out the cable efficiently in the deepest water special attention would have to be given to the character of the brake apparatus; and if the ordinary friction brakes now in vogue can be supplanted by something more free from the chances of undue heating, an advance will have been made. Such an innovation would be especially valuable in this connection, on account of the length of one of the sections—that between Vancouver and Fanning Island—being substantially greater than anything previously dealt with. This section, with a proper allowance for slack, &c., would run into some 3,500 nautical miles or more, as against 2,717 for the Brest-St. Pierre cable of 1869, the new French Atlantic line just laid being again materially longer.

It has been stated that if a cable were ever laid on the suggested route it could not be subsequently recovered. In reply to this, it may be pointed out that cables have already been picked up in depths of over 3,000 fathoms and repaired in the open sea.

Again, objections have been raised as to the length of time taken in the recovery of a cable in such depths. It must, however, be borne in mind that cables have been picked up and repaired in upwards of 2,000 fathoms within the course of two or three days.

The maximum speed of working obtainable on the long section (say 3,500 N.M.) with a large core would be low as compared with that attained on the Atlantic cables. Nevertheless, with a core of the same proportions as that adopted in the 'Anglo-American' Company's last cable—650lbs. copper to 400lbs. gutta-percha—under ordinary conditions a speed (in five letter words) could be attained up to the minimum required by the Canadian Government in 1894.

This would be by ordinary manual transmission, whereas all the latest improvements in machine transmission with curbing arrangements (as well as condensers) would naturally be applied with something like a 35 per cent. increase in the speed. The adoption of Muirhead's Duplex system would nearly double the working capacity of the cable.

As a first venture the above cable would probably be sufficient to meet the ends in view. It is conceivable that a larger core would be out of the question on the ground of cost. Moreover, increases in the dimensions made beyond this would have the effect of still further increasing the mechanical difficulties as regards a suitable type of sheathing.

Experiments have, it is believed, already been made on two Atlantic cables looped together to test the possibility of working through a considerably greater length than that to be dealt with here, with satisfactory results.

In the construction of the first cable to India (*viâ* the Persian Gulf) Messrs. Bright & Clark, as engineers to the Government, adopted a conductor in which four ordinary wires were drawn down so as to form the four quadrants of a true circle with a ring outside to embrace the whole.

By this means—with a given weight of copper—they reduced the electro-static (inductive) capacity of the core without increasing the conductor resistance, the result being a very material increase in the attainable speed of signalling, whilst sufficiently maintaining the mechanical requirements as regards pliability, &c.

Messrs. Siemens Brothers have since, to a great extent, approached a similar end in their compromise between the single solid wire and the ordinary strand conductor, and this has proved a great success on a number of Atlantic cables.

It would seem as though a plan of drawing the wires down to a smaller total area might in this undertaking be advantageously adopted. In the case of the Persian Gulf cable, an economical method of securing any particular speed was not of the same vital importance. Moreover, in that instance the length not being of an abnormal character, the extra cost of the above type of conductor was probably scarcely made good by increased working value. Here, however, the author is of opinion that this plan would be found to more than repay the increase in initial cost—especially as it would also materially reduce the quantity of gutta-percha required to obtain the same minimum thickness throughout for fulfilling mechanical as well as electrical qualifications, this being the *bête noire* in the cost of an ocean cable, as also in its design.

By way of improving the present means of signalling upon cables, Mr. Oliver Heaviside, F.R.S., has advocated the introduction of 'leak' circuits and self-induction into cable lines; and electrical engineers—including Mr. Preece, Dr. Thompson, and others—have devised new forms for the insulated conductor accompanied by devices which to a certain extent realised these theoretical advantages. The application of leaks on the ordinary cable, when suitably disposed along the line, would obviate the choking effect of retardation, and secure increased definition for the signals, though not sufficiently to permit of any substantial increase in the working speed, even with the battery power raised within reason.

A number of other proposals have been made, but, so far as concerns any further material increase in the speed attainable for submarine telegraphy under given conditions, it seems probable that if this is to be effected it will be by an entire revolution in the form of conductor, dielectric, and completed cable, rather than in the signalling apparatus. The latter has probably reached its limits of sensitiveness. Any further increased sensibility of the instruments is likely to be at the expense of steadiness, and would tend to bring them within the range of influence of other surrounding forces. It is even now quite beyond that required or justified by the cable itself under present conditions.

To the political, strategic, and commercial importance of this line the author has already drawn attention in the 'Fortnightly Review' for September, 1898.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION.—E. B. BRABROOK, C.B., F.S.A.

The President delivered the following Address on Friday, September 9 :—

I AM very sensible of the honour of being President of this Section at a Bristol meeting. Bristol, from its association with the memory of J. C. Prichard, may be regarded as the very birthplace of British Anthropology.

In submitting to the Section some observations on the past progress and the present position of the Anthropological Sciences, I use the plural term, which is generally adopted by our French colleagues, in order to remind you that Anthropology is in fact a group of sciences. There is what in France is called pure anthropology or anthropology proper, but which we prefer to call physical anthropology—the science of the physical characters of man, including anthropometry and craniology, and mainly based upon anatomy and physiology. There is comparative anthropology, which deals with the zoological position of mankind. There is prehistoric archæology, which covers a wide range of inquiry into man's early works, and has to seek the aid of the geologist and the metallurgist. There is psychology, which comprehends the whole operations of his mental faculties. There is linguistics, which traces the history of human language. There is folklore, which investigates man's traditions, customs, and beliefs. There are ethnography, which describes the races of mankind, and ethnology, which differentiates between them, both closely connected with geographical science. There is sociology, which applies the learning accumulated in all the other branches of anthropology to man's relation to his fellows, and requires the co-operation of the statistician and the economist. How can any single person master in its entirety a group of sciences which covers so wide a field, and requires in its students such various faculties and qualifications? Here, if anywhere, we must be content to divide our labours. The grandeur and comprehensiveness of the subject are among its attractions. The old saying, 'I am a man, and therefore I think nothing human to be foreign to me,' expresses the ground upon which the anthropological sciences claim from us a special attention.

I may illustrate what I have said as to the varied endowments of anthropologists by a reference to the names of four distinguished men who have occupied in previous years the place which it falls to my lot to fill to-day—most unworthily, as I cannot but acknowledge, when I think of their pre-eminent qualifications. When the Association last met at Bristol, in 1875, Anthropology was not a Section, but only a Department, and it was presided over by Rolleston. There may be some here who recollect the address he then delivered, informed from beginning to end with that happy and playful wit which was characteristic of him; but all will know how great he was in anatomy, what a wide range of classical and other learning he possessed, and how he delighted to bring it to bear on every anthropological subject that was presented to his notice. In 1878 Huxley was the Chairman of this Department. It is only necessary to mention the name of that illustrious biologist to recall to your memory how much anthropology owes to him. Eight years before, he had been President of the Association itself, and seven years before that had published his 'Evidence as to Man's Place in Nature.' Brilliant as his successes were in other branches of scientific investigation, I cannot but think that anthropology was with him a favourite pursuit. His writings upon that subject possess a wonderful charm of style. In 1883 the Chairman was Pengelly, who for many years rendered service to anthropology by his exploration of Kent's Cavern and other caves, and who happily illustrated the close relation that exists between geology and anthropology. His biography, recently published, must have reminded many of us of the amiable qualities which adorned his character. Finally, in 1886, two years after anthropology had become a Section, its President was Sir George Campbell, a practical ethnologist, a traveller, an administrator, a legislator, a geographer, who passed through a long career of public life with honour and distinction. All my other predecessors are, I am glad to say, still living, and I make no mention of them. The few names I have cited —selected by the accidental circumstance that they are no longer with us—are sufficient to show what varied gifts and pursuits are combined in the study of anthropology.

There is another side to the question. Great as is the diversity of the anthropological sciences, their unity is still more remarkable. The student of man must study the whole man. No true knowledge of any human group, any more than of a human individual, is obtained by observation of physical characters alone. Modes of thought, language, arts, and history must also be investigated. This simultaneous investigation involves in each case the same logical methods and processes. It will in general be attended with the same results. If it be true that the order of the Universe is expressed in continuity and not in cataclysm, we shall find the same slow but sure progress evident in each branch of the inquiry. We shall find that nothing is lost, that no race is absolutely destroyed, that everything that has been still exists in a modified form, and contributes some of its elements to that which is. We shall find that this, which no one doubts in regard to physical matters, is equally true of modes of thought. We may trace these to their germs in the small brain of the palæolithic flint-worker; or, if we care to do so, still farther back. This principle has, as I understand, been fully accepted in geology and biology, and throughout the domain of physical science—what should hinder its application to anthropology? It supplies a formula of universal validity, and cannot but add force and sublimity to our imagination of the wisdom of the Creator. It is little more than has been expressed in the familiar words of Tennyson:—

> 'Yet I doubt not thro' the ages one increasing purpose runs,
> And the thoughts of men are widen'd with the process of the suns;'

and supports his claim to be 'the heir of all the ages, in the foremost files of time.'

I propose, in briefly drawing your attention to some recent contributions to our knowledge, to use this as a convenient theory and as pointing out the directions in which further investigation may be rewarded by even fuller light.

Applying it, first of all, to the department of physical anthropology, we are called upon to consider the discovery by Dr. Dubois at Trinil, in Java, of the remains of an animal called by him *Pithecanthropus erectus,* and considered by some authorities to be one of the missing links in the chain of animal existence which terminates in man. In his Presidential Address to this Association last year, Sir John Evans said: 'Even the *Pithecanthropus erectus* of Dr. Eugène Dubois from Java meets with some incredulous objectors from both the physiological and the geological sides. From the point of view of the latter the difficulty lies in determining the exact age of what are apparently alluvial beds in the bottom of a river valley.' In regard to these objections, it should be remembered that, though the skull and femur in question are the only remains resembling humanity discovered in the site, it yielded a vast number of fossil bones of other animals, and that any difficulty in settling the geological age must apply to the whole results of the exploration. The physiological difficulties arise in two points—Do the skull and femur belong to the same individual? Are they or either of them human, or simian, or intermediate? As to the first, it is true that the two bones were separated by a distance of about fifty feet, but as they were found precisely on the same level, accompanied by no other bones resembling human bones, but by a great number of animal remains, apparently deposited at the same moment, the theory that they belonged to different individuals would only add to the difficulty of the problem. With regard to the skull, a projection of its outline on a diagram comparing it with others of low type belonging to the Stone Age shows it to be essentially inferior to any of them. With regard to the thigh, you will recollect that at the Liverpool meeting of this Section Dr. Hepburn displayed a remarkable collection of femora from the anatomical museum of Edinburgh University, exhibiting pathological and other conditions similar to those in the femur of Trinil. Though this evidence tends to show that the bone is human, it is not inconsistent with, but, on the contrary, goes to support the conclusion that it belongs to an exceedingly low and ancient type of humanity. Whether, therefore, we call the remains *Pithecanthropus erectus* with their discoverer, or *Homo pithecanthropus* with Dr. Manouvrier, or *Homo Javanensis primigenius* with Dr. Houzé, we are in presence of a valuable document in the early evolution of mankind.

One element of special interest in this discovery is that it brings us nearer than we have ever been brought before to the time when man or his predecessor acquired the erect position. I believe that it is acknowledged by all that the femur belonged to an individual who stood upright, and I presume that the capacity of the skull, being greater than that of any known anthropoid, is consistent with the same inference. The significance of that has been most clearly set forth by my predecessor, Dr. Munro, in his address to this Section at Nottingham in 1893. He showed that a direct consequence of the upright position was a complete division of labour as regards the functions of the limbs—the hands being reserved for manipulation and the feet for locomotion; that this necessitated great changes in the general structure of the body, including the pelvis and the spinal column; that the hand became the most complete and effective mechanical organ Nature has produced; and that this perfect piece of mechanism, at the extremity of a freely moving arm, gives man a superiority in attack and defence over other animals. Further, he showed that, from the first moment that man recognised the advantage of using a club or a stone in attack or defence, the direct incentive to a higher brain development came into existence. The man who first used a spear tipped with a sharp flint became possessed of an irresistible power. In his expeditions for hunting, fishing, gathering fruit, &c., primitive man's acquaintance with the mechanical powers of Nature would be gradually extended; and thus from this vantage point of the possession of a hand, language, thought, reasoning, abstract ideas would gradually be acquired, and the functions of the hand and the brain be developed in a corresponding manner. I do injustice to Dr. Munro's masterly argument by stating it thus crudely and briefly. It amounts to this—once the erect position is obtained, the actions of man being controlled by a progressive brain, everything follows in due course.

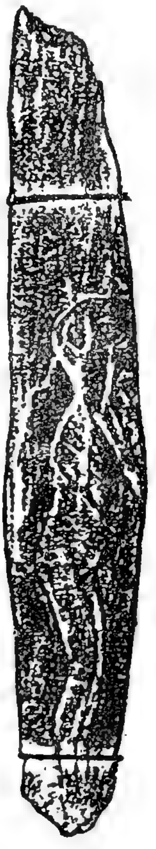
The next stage which we are yet able to mark with certainty is the palæolithic, but there must have been a great many intermediate stages. Before man began to make any implements at all, there must have been a stage of more or less length, during which he used any stick or stone that came to his hands without attempting to fashion the one or the other. Before he acquired the art of fashioning so elaborate an implement as the ordinary palæolithic axe or hammer, there must have been other stages in which he would have been content with such an improvement on the natural block of flint as a single fracture would produce, and would proceed to two or three or more fractures by degrees. It must have been long before he could have acquired the eye for symmetry and the sense of design, of adaptation of means to ends, which are expressed in the fashioning of a complete palæolithic implement. It is probable that such rude implements as he would construct in this interval would be in general hardly distinguishable from flints naturally fractured. Hence the uncertainty that attaches to such discoveries of the kind as have hitherto been made public. Professor McKenny Hughes, who speaks with very high authority, concludes a masterly paper in the 'Archæological Journal' with the statement that he has 'never yet seen any evidence which would justify the inference that any implements older than palæolithic have yet been found.' The name 'palæotalith' which had been suggested for pre-palæolithic implements seems to him unnecessary at present, as there is nothing to which it can be applied, and, as it will be long before it can be asserted that we have discovered the very earliest traces of man, he thinks it will probably be long before the word is wanted. An elaborate work on the ruder forms of implement, just published by M. A. Thieullen, of Paris, who has for many years been engaged in collecting these objects, adds materially to our knowledge of the subject.

Another line of argument bearing strongly in the same direction is afforded by the discovery in various places of works of art fabricated by early man. The statuettes from Brassempouy, the sculptures representing animals from the Bruniquel, the well-known figure of the mammoth engraved on a piece of ivory from Périgord, and many other specimens of early art, attest a facility that it is not possible to associate with the dawn of human intelligence. M. Salomon Reinach tells an amusing story. A statuette in steatite of a woman, resembling in some respects those of Brassempouy, was discovered in one of the caverns of Mentone as far back as 1884, but when the discoverer showed it to a personage in the locality that authority advised him not to let it be seen, lest it should take away from the belief in the antiquity of the caves, it being then thought too artistic to be consistent with early man. The finder acted on this advice, in ignorance of the real interest of the statuette, until April 1896, when he showed it to M. Reinach and M. Villenoisy, who promptly interviewed the sage adviser in question, and obtained a confirmation of the statement. Some interesting additions to our gallery of prehistoric art have been recently made by M. Emile Rivière and M. Berthoumeyrou, at Cro-Magnon, in the Dordogne. These are a drawing of a bison and another of a human female in profile, which M. Rivière has kindly allowed me to reproduce. Among the other objects found in the same place were some flint implements brought to a fine point, suitable for engraving on bone or horn.

The idea of making in any form a graphic representation of anything seen has never, so far as I know, occurred to any lower animal; and it could hardly have been among the first ideas formed in the gradually developing human brain. When that idea is found carried out with remarkable artistic skill, by means of implements well adapted for the purpose, we may surely assume that the result was not obtained till after a long interval of time, and was approached by gradual steps marked by progress in other faculties, as well as in the artistic faculty. It may be that some day all uncertainty on this head will be removed by decisive discoveries.

The interval between the Palæolithic and Neolithic periods rests in the like condition of incertitude. That by some means, and somewhere on the face of the globe, the one period gradually passed into the other, we cannot but believe. That the transition between them may have involved innumerable degrees is also highly probable. Where and when, and how each step was taken, we do not know at present, and possibly never shall know. The problem is not satisfactorily solved by the production of palæolithic implements resembling neolithic forms or neolithic implements resembling palæolithic forms; inasmuch as between the one period and the other an interval of time involving geological and other changes has to be accounted for.

In this respect, also, our best authorities are the most cautious and conservative. In the excellent address which Professor Boyd Dawkins delivered to the Royal Archæological Institute at the Dorchester meeting last year, on the present phase of prehistoric archæology, he contrasted the few primitive arts, such as sewing, and the manufacture of personal ornaments and rude implements of the chase, possessed by the palæolithic hunters—apart from their great proficiency in the delineation of animals—with the variety of arts, such as husbandry, gardening, spinning, weaving, carpentry, boat-building, mining, and pottery-making, possessed by the neolithic herdsmen, and held that between the two there is a great gulf fixed. Somewhere that gulf must be bridged over. Professor Boyd Dawkins says that the bridge is not to be found in the caverns of the South of France. It is difficult to meet his argument that the presence of grains of barley and stones of the cultivated plum at Mas d'Azil are evidences of neolithic civilisation. His objections to other discoveries are not so strong as this, but are strong enough to make us pause. The tall, long-headed people, whose remains were found at Cro-Magnon, he holds to be early neolithic and not palæolithic, to stand on the near side and not on the far side of the great gulf.



These considerations lend importance to the discoveries which have been laid before this Association at previous meetings by Mr. Seton-Kerr, and which have also been commented upon by Professor Flinders Petrie and Sir John Evans. If we are compelled to admit a breach of continuity in Europe, is it in Africa that we shall find the missing links? That is another of the great problems yet unsolved. The evidence we want relates to events which took place at so great a distance of time that we may well wait patiently for it, assured that somewhere or other these missing links in the chain of continuity must have existed and probably are still to be found.

The next stage, which comprises the interval between the neolithic and the historic periods, was so ably dealt with by Mr. Arthur J. Evans in his address to this Section at the Liverpool meeting that it does not call for any observations from me. Two Committees appointed by the Association in connection with this Section touch upon this interval—the Committee for investigating the lake dwellings at Glastonbury, and the Committee for co-operating with the explorers of Silchester in their well-conducted and fruitful investigation of the influence of Roman civilisation on a poor provincial population. I pass on to consider the very great progress that has been made of late years in some of the branches of anthropology other than physical and prehistoric, and especially in that of folk-lore. I do this the more readily because I do not recollect that folk-lore has ever before been prominently referred to in an Address to this Section. It is beginning to assert itself here, and will in time acquire the conspicuous position to which it is becoming entitled, for the British Association is sensitive to every scientific movement, and responds readily to the demands of a novel investigation. Already, for three or four years, a day has been given at our meetings to folk-lore papers; and at the Liverpool meeting an exceedingly philosophic, and at the same time practical, paper was read by Mr. Gomme, and is printed *in extenso* in the Proceedings as an Appendix to the Report of the Ethnographic Survey Committee. The term 'folk-lore' itself is not without a certain charm. It is refreshing to find a science described by two English syllables instead of by some compound Greek word. The late Mr. W. J. Thoms had a happy inspiration when he invented the name. It is just twenty years since the Folk-lore Society was established under his direction. It has accumulated a vast amount of material, and published a considerable literature; it is now rightly passing from the stage of collection to that of systematisation, and the works of Mr. J. G. Frazer, Mr. E. Sidney Hartland, and others, are pointing the way towards researches of the most absorbing interest and the greatest practical importance.

A generalisation for which we are fast accumulating material in folk-lore is that of the tendency of mankind to develop the like fancies and ideas at the like stage of intellectual infancy. This is akin to the generalisation that the stages of the life of an individual man present a marked analogy to the corresponding stages in the history of mankind at large; and to the generalisation that existing savage races present in their intellectual development a marked analogy to the condition of the earlier races of mankind. The fancies and ideas of the child resemble closely the fancies and ideas of the savage and the fancies and ideas of primitive man.

An extensive study of children's games, which had been entered into and pursued by Mrs. Gomme, has been rewarded by the discovery of many facts bearing upon these views. A great number of these games consist of dramatic representations of marriage by capture and marriage by purchase—the idea of exogamy is distinctly embodied in them. You will see a body of children separate themselves into two hostile tribes, establish a boundary line between them, demand the one from the other a selected maiden, and then engage in conflict to determine whether the aggressors can carry her across the boundary or the defenders retain her within it.

There can be little doubt that these games go back to a high antiquity, and there is much probability that they are founded upon customs actually existing, or just passing away at the time they were first played. Games of this kind pass down with little change from age to age. Each successive generation of childhood is short:—the child who this year is a novice in a game becomes next year a proficient, and the year after an expert, capable of teaching others, and proud of the ability to do so. Even the adult recollects the games of childhood and watches over the purity of the tradition. The child is ever a strong conservative.

Upon the same principle, next to children's games, children's stories claim our attention. Miss Roalfe Cox has collected, abstracted, and tabulated not fewer than 345 variants of Cinderella, Catskin, and Cap o' Rushes. These come from all four quarters of the globe, and some of them are recorded as early as the middle of the sixteenth century. These elaborate stories are still being handed down from generation to generation of children, as they have been for countless generations in the past. Full of detail as they are, they may be reduced to a few primitive ideas. If we view them in their wealth of detail, we shall deem it impossible that they could have been disseminated over the world as they are otherwise than by actual contact of the several peoples with each other. If we view them in their simplicity of idea, we shall be more disposed to think that the mind of man naturally produces the same result in the like circumstances, and that it is not necessary to postulate any communication between the peoples to account for the identity. It does not surprise us that the same complicated physical operations should be performed by far-distant peoples without any communication with each other: why should it be more surprising that mental operations, not nearly so complex, should be produced in the same order by different peoples without any such communication? Where communication is proved or probable, it may be accepted as a sufficient explanation; where it is not provable, there is no need that we should assume its existence.

The simple ideas which are traceable in so many places and so far back are largely in relation with that branch of mythology which personifies the operations of Nature. Far be it from me to attempt to define the particular phase of it which is embodied in the figure of Cinderella as she sits among the ashes by the hearth, or to join in the chase after the solar myth in popular tradition. The form of legend which represents some of the forces of Nature under the image of a real or fictitious hero capable of working wonders appears to be widely distributed. Of such, I take it, are the traditions relating to Glooscap, which the late Dr. S. T. Rand collected in the course of his forty years' labours as a missionary among the Micmac Indians of Nova Scotia, where, Mr. Webster says, Glooscap formerly resided. The Indians suppose that he is still in existence, although they do not know exactly where. He looked and lived like other men; ate, drank, smoked, slept, and danced along with them; but never died, never was sick, never grew old. Cape Blomidon was his home, the Basin of Minas his beaver-pond. He had everything on a large scale. At Cape Split he cut open the beaver dam, as the Indian name of the cape implies, and to this we owe it that ships can pass there. Spencer's Island was his kettle. His dogs, when he went away, were transformed into two rocks close by. When he returns he will restore them to life. He could do anything and everything. The elements were entirely under his control. You do not often meet with a mischievous exercise of his power. It is a curious part of the tradition, possibly a late addition to it, that it was the encroachments and treachery of the whites which drove him away.

The early inhabitants of the island of Tahiti appear to have had a whole pantheon of gods and heroes representing the various operations of Nature. Even the Papuans have a legend in which the morning star is personified acting as a thief. But it is needless to multiply instances. Lord Bacon—who says 'The earliest antiquity lies buried in silence and oblivion. . . . This silence was succeeded by poetical fables, and these at length by the writings we now enjoy; so that the concealed and secret learning of the ancients seems separated from the history and knowledge of the following ages by a veil or partition wall of fables interposing between the things that are lost and those that remain'—has shown in his 'Wisdom of the Ancients' that classical mythology was in truth a vast system of Nature-worship, and in so doing has done more than even he knew, for he has affiliated it to those ideas which have been so commonly formed among rude and primitive peoples. It is true, he says, fables in general are composed of ductile matter, that may be drawn into great variety by a witty talent or an inventive genius, and be delivered of plausible meanings which they never contained. But the argument of most weight with him, he continues, 'is that many of these fables by no means appear to have been invented by the persons who relate and divulge them, whether Homer, Hesiod, or others; but whoever attentively considers the thing will find that these fables are delivered down and related by those writers, not as matters then first invented and proposed, but as things received and embraced in earlier ages. The relators drew from the common stock of ancient tradition, and varied but in point of embellishment, which is their own. This principally raises my esteem of these fables, which I receive, not as the product of the age or invention of the poets, but as sacred relics, gentle whispers, and the breath of better times, that from the traditions of more ancient nations came, at length, into the flutes and trumpets of the Greeks.'

Except that he supposes them to be a relic of better times, the poet's dream of a golden age no doubt still ringing in his ears, Bacon had, in this as in many other matters, a clear insight into the meaning of things.

Another idea that appears among very early and primitive peoples, and has had in all time a powerful influence on mankind, is that of a separable spirit. The aborigines of North-West Central Queensland, who have lately been studied to such excellent purpose by Dr. Walter Roth, the brother of a much-esteemed past officer of this Section, are in many respects low in the scale of humanity; yet they possess this idea. They believe that the ghost, or shade, or spirit of some one departed can so initiate an individual into the mysteries of the craft of doctor or medicine-man as to enable him, by the use of a death-bone apparatus, to produce sickness and death in another. This apparatus is supposed to extract blood from the victim against whom it is pointed without actual contact, and to insert in him some foreign substance. They will not go alone to the grave of a relative for fear of seeing his ghost. It appears that they have the fancy that Europeans are ghosts. The Tasmanians also, as Mr. Ling Roth himself tells us, had the same fancy as to the Europeans, and believed that the dead could act upon the living. The Pawnee Indians, we are assured by Mr. Grinnell, believe that the spirits of the dead live after their bodies are dust. They imagine that the little whirlwinds often seen in summer are ghosts. The Blackfeet think the shadow of a person is his soul, and that while the souls of the good are allowed to go to the sand-hills, those of the bad remain as ghosts near the place where they died. The Shillooks of Central Africa are said to believe that the ghostly spectres of the dead are always invisibly present with the living, and accompany them wherever they go. The aborigines of Samoa believed in a land of ghosts, to which the spirits of the deceased were carried immediately after death. The religious system of the Amazulu, as described by Bishop Callaway, rests largely on the foundation of belief in the continued activity of the disembodied spirits of deceased ancestors.

Mr. Bryce, in his 'Impressions of South Africa,' says that at Lezapi, in Mashonaland, are three huts, one of which is roofed, and is the grave of a famous chief, whose official name was Makoni. 'On the grave there stands a large earthenware pot, which used to be regularly filled with native beer when, once a year, about the anniversary of his death, his sons and other descendants came to venerate and propitiate his ghost Five years ago, when the white men came into the country, the ceremony was disused, and the poor ghost is now left without honour and nutriment. The pot is broken, and another pot, which stood in an adjoining hut, and was used by the worshippers, has disappeared. The place, however, retains its awesome character, and a native boy who was with us would not enter it. The sight brought vividly to mind the similar spirit worship which went on among the Romans, and which goes on to-day in China; but I could not ascertain for how many generations back an ancestral ghost receives these attentions—a point which has remained obscure in the case of Roman ghosts also.'

The aborigines of New Britain are said to believe that the ghosts of their deceased ancestors exercise a paramount influence on human affairs, for good or for evil. They have the poetical idea that the stars are lamps held out by the ghosts to light the path of those who are to follow in their footsteps. On the other hand, they think these ancestral ghosts are most malicious during full moon. Not to multiply instances, we may say with Mr. Staniland Wake, it is much to be doubted whether there is any race of uncivilised men who are not firm believers in the existence of spirits or ghosts. If this is so, and the idea of a separable spirit, capable of feeling and of action apart from the body, is found to be practically universal among mankind, and to have been excogitated by some of the least advanced among peoples; and if we observe how large a share that idea has in forming the dogmas of the more specialised religions of the present day, we shall not see anything inherently unreasonable in the generalisation that the group of theories and practices which constitute the great province of man's emotions and mental operations expressed in the term 'religion' has passed through the same stages and produced itself in the same way from these early rude beginnings of the religious sentiment as every other mental exertion. We shall see in religion as real a part of man's organisation as any physical member or mental faculty. We shall have no reason to think that it is an exception to any general law of progress and of continuity which is found to prevail in any other part of man's nature.

The same inference may be drawn from many other considerations. Take, for instance, the belief in witchcraft, which is so characteristic of uncivilised man that it is hardly necessary to cite examples of it. The Rev. Mr. Coillard, a distinguished missionary of the Evangelical Society of Paris, in a delightful record, which has just been published, of his twenty years' labours as a missionary pioneer among the Banyai and Barotzi of the Upper Zambesi, 'on the threshold of Central Africa,' says: 'In the prison of the Barotzi, toiling at earthworks, is a woman—young, bright, and intelligent. She told me her story. A man of remarkably gentle character had married her. The king's sister, Katoka, having got rid of one of her husbands, cast her eyes on this man and took him. He had to forsake his young wife—quite an easy matter. Unfortunately, a little later on, a dead mouse was found in the princess's house. There was a great commotion, and the cry of witchcraft was raised. The bones did not fail to designate the young woman, and she was made a convict. A few years ago she would have been burnt alive. Ah, my friends, paganism is an odious and a cruel thing!' Ah, Mr. Coillard, is it many years ago that she would have been burnt alive or drowned in Christian England or Christian America? Surely the odiousness and the cruelty are not special to paganism any more than to Christianity. The one and the other are due to ignorance and superstition, and these are more hateful in a Matthew Hale or a Patrick Henry than in a Barotzi princess in the proportion that they ought to have been more enlightened and intelligent than she. It is only 122 years since John Wesley wrote: 'I cannot give up to all the Deists in Great Britain the existence of witchcraft;' and I believe that to this day the Order of Exorcists is a recognised order in the Catholic Church.

The same line of argument—which, of course, I am only indicating here—might be pursued, I am persuaded, in numberless other directions. Mr. Frazer, in his work on the Golden Bough, has most learnedly applied it to a remarkable group of beliefs and observances. Mr. Hartland has followed up that research with a singularly luminous study of several other groups of ideas in the three volumes of his 'Legend of Perseus.' More recently, Mr. Andrew Lang has sought to show that the idea of a Supreme Being occurs at an earlier stage in the development of savage thought than we had hitherto supposed. Striking as these various collocations of facts and the conclusions drawn from them may appear, I am convinced there is much more for the Folk-lorist to do in the same direction.

The principle that underlies it all seems to be this: man can destroy nothing, man can create nothing, man cannot of his own mere volition even permanently modify anything. A higher power restrains his operations, and often reverses his work. You think you have exterminated a race: you have put to the sword every male you can find, and you have starved and poisoned all the survivors of the community. In the meanwhile, their blood has been mingled with yours, and for generations to come your bones and those of your descendants will preserve a record of that lost race. You think you have exterminated a religion: you have burned to death all of its teachers you can find, and converted forcibly or by persuasion the rest of the community. But you cannot control men's thoughts, and the old beliefs and habits will spring up again and again, and insensibly modify your own religion, pure as you may suppose it to be.

Huxley, in his address to the department of Anthropology twenty years ago, said, with the force and candour that were characteristic of him: 'Anthropology has nothing to do with the truth or falsehood of religion—it holds itself absolutely and entirely aloof from such questions—but the natural history of religion, and the origin and the growth of the religions entertained by the different kinds of the human race, are within its proper and legitimate province.' I do not presume to question that as an absolutely accurate definition of the position—it could not be otherwise; but if there be any here to whom what I have been suggesting is in any sense novel or startling, I should be glad to be allowed to say one word of reassurance to them. When my friend Mr. Clodd shocked some of the members of the Folk-lore Society by his frank statement of conclusions at which he had arrived, following the paths I have indicated, it was said we must fall back on the evidences of Christianity. What more cogent evidence of Christianity can you have than its existence? It stands to-day as the religion which, in most civilised countries, represents that which has been found by the operation of natural laws to be best suited for the present circumstances of mankind. You are a Christian because you cannot help it. Turn Mohammedan to-morrow—will you stop the spread of Christianity? Your individual renunciation of Christianity will be but a ripple on a wave. Civilised mankind holds to Christianity, and cannot but do so till it can find something better. This, it seems to me, is a stronger evidence of Christianity than any of the loose-jointed arguments I find in evidential literature.

Upon this thorny subject I will say no more. I would not have said so much, but that I wish to show that these considerations are not inconsistent with the respect I entertain, and desire now as always to express, for those feelings and sentiments which are esteemed to be precious by the great majority of mankind, which solace them under the adversities of life and nerve them for the approach of death, and which stimulate them to works of self-sacrifice and of charity that have conferred untold blessings on humanity. I reverence the divine Founder of Christianity all the more when I think of Him as one who so well 'knew what was in man' as to build upon ideas and yearnings that had grown in man's mind from the earliest infancy of the race.

To return. If continuity be the key that unlocks the receptacle where lie the secrets of man's history—physical, industrial, mental, and moral; if in each of these respects the like processes are going on—it follows, as I have already said, that the only satisfactory study of man is a study of the whole man. It is for this reason that I ask you to take especial interest in the proceedings of one of the Committees of this Section, which has adopted such a comprehensive study as the guiding principle of its work—I mean the Ethnographical Survey Committee. I have so often addressed this Section and the Conference of Corresponding Societies on the matter, since the Committee was first appointed at the Edinburgh meeting, on the suggestion of my friend Professor Haddon, that I can hardly now refer to it without repeating what has been already said or forestalling what will be said when its report is presented to you, but its programme so fully realises that which has been in my mind in all that I have endeavoured to say that I must make one more effort to enlist your active interest in its work.

The scheme of the Committee includes the simultaneous recording in various districts of the physical characters, by measurement and by photography, the current traditions and beliefs, the peculiarities of dialect, the monuments and other remains of ancient culture, and the external history of the people. The places in the United Kingdom where this can be done with advantage are such only as have remained unaffected by the great movements of population that have occurred, especially of late years. It might have been thought that such places would be very few; but the preliminary inquiries of the Committee resulted in the formation of a list of between 300 and 400. So far, therefore, as the testimony of the very competent persons whose advice was sought by them is to be relied on, it is evident that there is ample scope for their work. At the same time, the process of migration from country to town is going on so rapidly, that every year diminishes the number of such places. One thinks with regret how much easier the work would have been one or two or three generations ago; but that consideration should only induce us to put it off no longer. The work done by the lamented Dr. Walter Gregor for this Committee in Dumfriesshire and other parts of Scotland is an excellent type of the way in which such work should be done. His collections of physical measurements and of folk-lore have been published in the fourth and fifth reports of the Committee. There can be no doubt that few men possess the faculty he had of drawing forth the confidence of the villagers and getting them to tell him their superstitions and their old customs. He succeeded in recording from their lips not fewer than 733 items of folk-lore. They not merely form exceedingly pleasant reading, such as is perhaps not often met with in a British Association Report, but they also will be found to throw considerable light on the views which I have ventured to lay before you. It is much to be wished that others who have the like faculty, if even in a lesser degree, could be induced to take up similar work in other districts, now that Dr. Gregor has so well shown the way in which it ought to be done.

The work done by the Committee for the Ethnographical Survey of Canada; the completion of the Ethnographical Survey of the North-Western tribes which has been ably conducted for many years; and the progress made in the Ethnographical Survey of India will also be brought under your notice, the latter in a paper by Mr. Crooke, who has worked with Mr. Risley upon it.

Another movement, which was originated by this Section at the Liverpool meeting, and was referred to in the report of the Council of the Association last year, has made some progress since that report was presented. Upon the recommendation of this Section, the General Committee passed the following resolution and referred it to the Council for consideration and action:—

> 'That it is of urgent importance to press upon the Government the necessity of establishing a Bureau of Ethnology for Greater Britain, which, by collecting information with regard to the native races within and on the borders of the Empire, will prove of immense value to science and to the Government itself.'

The Council appointed a Committee, consisting of the President and General Officers, with Sir John Evans, Sir John Lubbock, Professor Tylor, and your esteemed Vice-President, Mr. Read, the mover of the resolution. Their report is printed at length in last year's Report of Council, and shows clearly how useful and how easily practicable the establishment of such a Bureau would be. The Council resolved that the Trustees of the British Museum be requested to consider whether they could allow the proposed Bureau to be established in connection with the Museum. I understand that those Trustees have returned a favourable answer; and I cannot doubt that the joint representations which they and this Association will make to Her Majesty's Government will result in the adoption of a scheme calculated to realise all the advantages which we in this Section have so long looked for from it. In the Secretary of State for the Colonies and the Chancellor of the Exchequer we have statesmen who cannot fail to appreciate the benefits the community must derive from acquiring accurate and scientific knowledge of the multifarious races which compose the Empire.

Those of us who visited the United States last year had the opportunity of observing the excellent work which is done by the Bureau of Ethnology at Washington, and those who stayed at home are probably familiar with the valuable publications of that department. An Act of Congress twenty years ago appropriated 4,000*l*. a year to the Smithsonian Institution for the continuance of researches in North American anthropology. The control of the Bureau was entrusted to the able hands of Major Powell, who gathered round him a band of skilled workers, many of whom had been previously engaged on ethnographic research under the direction of the Geographical and Geological Survey of the Rocky Mountain region. In field work and in office work, to use Major Powell's convenient distinction, ample return has ever since been rendered to the United States Government for the money thus appropriated, which has since been increased to 8,000*l*. a year. Our own Bureau of Ethnology would have a wider sphere of operations, and be concerned with a greater number of races. It would tend to remove from us the reproach that has in too many cases not been without foundation—that we have been content to govern races by the strong hand without caring to understand them, and have thus been the cause of injustice and oppression from ignorance rather than from malevolence. If that were only a record of the past, we might be content with mere unavailing regret; but the colonial empire is still expanding, and we and our competitors in that field are still absorbing new districts—a practice which will probably continue as long as any spot of ground remains on the face of the globe occupied by an uncivilised race.

Would it not be worth while at this juncture to extend to the peoples of Africa, for instance, the principles and methods of the Ethnographic Survey—to study thoroughly all their physical characters, and at the same time to get an insight into the working of their minds, the sentiments and ideas that affect them most closely, their convictions of right and wrong, their systems of law, the traditions of the past that they cherish, and the rude accomplishments they possess? If for such a service investigators like Dr. Roth, who began his researches in Queensland by so close a study of the languages and dialects of the people that he thoroughly won their confidence, could be found, the public would soon learn the practical value of anthropological research. If the considerations which I have endeavoured to urge upon you should lead not only the scientific student but the community at large to look upon that which is strange in the habits and ways of thinking of uncivilised peoples as representing with more or less accuracy a stage in that long continuity of mental progress without which civilised peoples would not be what and where they are, it could not but favourably affect the principles and practice of colonisation. *Tout comprendre c'est tout pardonner.* The more intimate our acquaintance with the races we have to deal with and to subjugate, the more we shall find what it means to stand with them on the same platform of common humanity. If the object of government be, as it ought to be, the good of the governed, it is for the governing race to fit itself for the task by laying to heart the lessons and adopting the processes of practical anthropology.

THURSDAY, SEPTEMBER 8.

The following Report and Papers were read:—

1. *Report on Mental and Physical Deviations in Children.*
See Reports, p. 691.

2. *On Human Life at Extreme Altitudes. By* O. H. HOWARTH.

The observations recorded by the author were made—(*a*) throughout the great mountain ranges of North America from Oregon to the south of Mexico, chiefly within the last ten years, and (*b*) in the Great Andes, and in European ranges, at earlier dates.

The author emphasises the importance of the collection of evidence of human settlement at very high altitudes in early times, due allowance being made for subsequent geological changes of altitude. Stone carvings, for example, of the earliest Central American types are found on the slopes of Popocatepetl, in Mexico, at altitudes between 8,000 feet and 10,000 feet.

The primary causes which have induced human settlement at extreme altitudes have been—(1) the pursuit of some local art or industry, which could not be followed elsewhere; (2) seclusion for religious purposes. Instances of both are not infrequent in the great ranges of the West, from California to Guatemala, and in the Cordillera of South America; and several instances of the latter occur in Mexico and Central America.

Conditions favourable to the persistence of human life among *natives* of high altitudes are—(1) immunity from certain diseases, especially of the respiratory organs, phthisis and diphtheria being apparently unknown above 6,000 feet; (2) the sedative effects of an attenuated atmosphere upon those who have been habituated to it from birth; (3) the preference for simple forms of nourishment and an active life, which follows from the surrounding conditions; (4) the peculiarly transient effects of alcoholic and all other artificial stimulants; (5) the sense of intensified vitality due to more rapid respiration and heart-action, though this may be at the expense of the duration of life.

Against these advantages must be set—(1) a diminution of brain development, which is transmittible and becomes very marked within three or four generations; (2) the effects of isolation frequently accompanying such a life (these have been noted in many parts of the American ranges, as well as in the Alps, and the Great Atlas of North Africa); (3) certain modified forms of disease, which seem to be incidental to extreme altitudes.

Numerous specialised forms of superstition and traditional belief arise out of the circumstances of high altitudes, especially some connected with sun worship, mining, the forms or habits of mountain fauna, and the reappearance of disembodied spirits.

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3. *On the Human Ear as a Means of Identification. By* Miss M. A. Ellis.

1. For purposes of identification the *helix*, or outer rim of the ear, and the general shape of the *pinna*, or whole outer ear, are the most useful features. Ears do not change shape after childhood, although they enlarge slightly after middle life.

2. It is possible to catalogue the great varieties of shape that are found to occur by marking off the *helix* into five divisions—viz. (1) from the neck of the ear to the top, (2) the top, (3) the turn, (4) the slope half way to the lobe, (5) the rest of the slope to the lobe. These are the natural divisions in well-formed ears, though seldom more than two or three of them are seen distinctly formed in the same ear.

3. From the varieties of sixty-four pairs of ears—many belonging to individuals noted in art, science, or literature—printed from life by the writer, it has been found that the right and left of each pair of ears usually vary in shape. Generally the most distinctive features are found in the upper half of the left ear and the lower half of the right ear. The educated upper classes exhibit the greater variety, and can be more easily identified than the 'masses.'

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4. *On Tabu in Japan in Ancient, Mediæval, and Modern Times.*
By K. Minakata.

The author described the *tabu* observances of Japan in three successive periods.

In the first, from the earliest times to 710 A.D., an indigenous and elaborate system of *tabu* prevailed respecting the person and name of the Emperor, the Imperial family, the nobles, chiefs, priests and priestesses, the temples with their properties and servants, certain trees and animals, sick persons, dead bodies, preparations for warfare, certain totems, days, times, directions, and unclean objects such as garlic and venison. The system was extended to the nether land of darkness, wherein this world's vegetation was *tabu* to those souls who would partake of food cooked on an infernal hearth.

In the second period, from 710 A.D. to the Restoration of 1867 A.D., this indigenous system was largely overlaid and, on the whole, relaxed by beliefs introduced together with the Chinese and Indian cultures, some socially pernicious *tabus* being prohibited strictly by law. But at the same time numerous fresh restrictions, appropriate to Tanist and Mantranist magic, came into vogue; and the Buddhist theory of universal metempsychosis gravely impressed upon the popular mind an abhorrence of many kinds of food.

In the third period, from 1867 A.D. onward, this heterogeneous and complicated *tabu* system was officially abolished; but a number of primitive *tabus*, mostly connected with the Shintoist ritual, were at the same time restored, though the only *tabu* which remains of social importance is that which relates to the death of close relatives.

The author ascribes in great part to the *tabu* system thus outlined the loyalty, probity, and courtesy of the Japanese, and their close observance of the forms of natural objects and historic scenes evinced by their art and literature.

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5. *On Stone Implements from South Africa. By* George Leith.

The author narrated the results of his investigation in cave shelters, in remote parts of the Stormberg, described the situation and characteristics of the bushmen's haunts, and told how, in some of them, were found implements and other signs of occupation, just as they had been left years ago. He remarked upon the various types of stone implements, such as the grinding stones, pounding stones, flaken hammers, arrow points, scrapers, &c., as being found both in the cave deposit and in the talus in front of the cave. The bushmen with these poisoned arrows were a dangerous enemy to the Boers, even when the latter were equipped with firearms.

The prevalent type of instrument was the scraper, knife-shaped and axe-shaped specimens being comparatively rare. Lighthouse Cave, at Cape St. Blaise, referred to by Sir John Barrow in his travels, was described. Investigations of this cave led to the discovery of many very fine specimens of skinning knives, scrapers, work in flaked implements, and seemed to show that it had been a place for the manufacture of these implements for many ages. He described the discovery of three Hottentots living in a cave, in prehistoric condition, occupied in digging out cave deposit which was used by the farms in the neighbourhood as manure. In the recess of the cave large quantities of bone were found, evidently having been stored away.

The author has discovered in various beds of gravel at various altitudes large numbers of palæolithic stone implements of very remarkable size and shape. These he classified according to their position into neolithic or modern, palæolithic or ancient, and æolithic, the latter being rude blocks of stone, whose acute angles showed undoubted evidences of having been notched by hand. The evidence of these gravels proved without doubt, in the opinion of the author, that South Africa was the home of man at a very remote period of history. A remarkable fact was that æoliths found there corresponded exactly with the plateau implements found on the Kentish Weald by Mr. Harrison, and recently the subject of much controversy.

6. *On some Roman Symbolic Hands.* *By* F. T. Elworthy.

After a reference to his paper on *Dischi Sacri* ('Proc. Soc. Antiq.,' vol. xvii. series ii. p. 59), and to symbolic hand-gestures elsewhere, the author contends that these hands are not votive offerings, as Gori inferred from a single inscribed specimen (No. 17), but objects of household worship. The following examples were illustrated and described:—

1. Berlin Museum: published by Caussens. 'Thes. Rom. Antiq.' vol. xii. pp. 963; copied by Montfaucon (French ed.), vol. ii. p. 330; Boettiger, 'Opuscula,' Taf. ii.; Jahn, 'Ber. d. k. Ges. d. Wiss. z. Leipzig,' 1855, Taf. iv.
2-3. Naples Museum, No. 5505: *two* hands unpublished.
4. Naples Museum, No. 5506: 'Bronze d'Ercolano,' vol. vii. p. 37; 'Antichità d'Ercolano,' vol. i. Tav. v.
5. Naples Museum, No. $\frac{595}{384}$: found at Pompeii, 1894; unpublished.
6. Naples Museum: unpublished.
7. Rome, Museo Kircheriano: found on the Isola Farnese, Rome; Montfaucon, vol. ii. Pl. 137; Jahn, *l. c.* p. 101.
8. Rome, Museo Kircheriano: unpublished.
9. Paris, Louvre: unpublished.
10. Zurich Museum: found at Avenches; Meyer, 'Mitth. d. Antiq. Ges. z. Zurich,' vol. xi. heft 12.
11. Zurich Museum: found at Zion; unpublished.
12. Brescia Museum: found recently; unpublished.
13. Brescia Museum: found recently; unpublished.
14. Leyden Museum: unpublished; cf. Meyer, *l.c.*
15. British Museum: Payne Knight Collection; Elworthy, 'Evil Eye,' p. 318.
16. ?———: found at Tournay; Montfaucon, vol. ii. Pl. 137.
17. ?———: Gori, 'Inscr. Antiq.' (Florence, 1643), vol. iii., Pl. 5.
18. ?———: 'Diss. della P. Acad. d. Arch.' (Rome, 1836), vol. viii., p. 427.

19. ?——: the only known *left* hand; Caylus, 'Tubières, Recueil,' vol. v., Pl. 63.

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7. *On the Boat-building of Siam.*
By H. Warington Smyth, *M.A.*, *F.R.G.S.*

The author describes the river craft in use among the Siamese, showing how admirably adapted is each type of boat to the waters it is used to navigate—the teak-built *rua pet* and rice boat to the lower reaches, and the long *rua nua* or northland boat of *thingan* wood used on the upper waters of the Me Nam.

The construction of the 'dug-out' Me Kawng boats is then explained, with the bamboo fittings along the gunwale which render them uncapsizable and unsinkable in the worst rapids of that wild torrent.

In describing the sea-going craft met with on the coasts of Siam, the primitive Malay lugger of the Peninsula, the *rua pet* of the Gulf, with her spoon-shaped bow, her wood fastenings, and high-peaked lug sails, the *rua chalom* of the native Chinese traders, with her peculiar double rudders, and the Chinese junk itself are all touched upon, and the advantages of their various peculiarities in build and rig pointed out.

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8. *On the Reed Organ of the Lao Shans.*
By H. Warington Smyth, *M.A.*, *F.R.G.S.*

A brief description is given of the simple fourteen-reed instrument in use among the Lao of the Me Kawng Valley, and an example of the characteristic and mono tonous music which rises and falls on moonlight nights in every jungle village inhabited by these people is added by the author.

FRIDAY, SEPTEMBER 9.

The President's Address was delivered (see p. 999).

The following Papers were read :—

1. *On the Mediæval Population of Bristol.*
By John Beddoe, *M.D.*, *F.R.S.*

The author based his conclusions on two series of skulls, the one mediæval, the other probably of the eighteenth century, disinterred on the occasion of the removal of St. Werburgh's Church, and on certain lists of surnames of various dates. He found the mediæval skulls very generally small, short, and broad (kephalic index 80·0), while the later ones exhibited the same long types that characterise the present population of Bristol and the surrounding districts (index 76·6). He ascribed the mediæval brachykephalism to the larger proportion of people of French descent which is indicated by that of French surnames, these latter having gradually declined in number ever since the fourteenth century.

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2. *Note on the Origin of Stone-worship.* *By* Professor H. A. Miers.

It is pointed out that among the various sources to which stone-worship is ascribed in anthropological works mention is rarely, if ever, made of the worship of meteorites; it is urged that when meteorites fell in early times—and there is no reason to believe that they fell less frequently than now—they must have provoked religious awe. Several instances are quoted among recorded falls in which this was certainly the case, and some in which the meteorite became an object of worship. The author suggests that the occasional possibility of such an origin of stone-worship should always be kept in view.

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3. *On the Prehistoric Antiquities of the Neighbourhood of Bristol.*
By Professor C. LLOYD MORGAN.

The author gave a short account, illustrated by lantern slides, of the camps and megalithic remains to be visited during the meeting in connection with excursions. The chief point of novelty and interest was the exposure of some of the 'dry walling' of the Stokeleigh Camp on the Somerset side of the Avon just across the Clifton Suspension Bridge. Excavations had been made which showed that the main rampart was crowned by a wall, footed on the heaped-up mass of Carboniferous limestone fragments, the base protected by large and massive stones. This 'dry walling' differs somewhat from that described by W. C. W. Dymond at Warlebury. There is no mortar; and the work may be regarded as undoubtedly pre-Roman.

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4. *On the Circles of Stanton Drew.*
By A. L. LEWIS, *F.C.A., Treas. Anthr. Inst.*

The author showed that the diameters of the circles, and the distances between them and the other stones forming this group of monuments were in carefully measured proportions, after allowing for a smaller error of workmanship than is usually found in early British remains. The significant numbers 5, 7, 9, and 19 are particularly prominent in the proportions. The different members of the group were also arranged in lines with each other in a manner which could not have been the result of mere accident. The author preferred not to hinder the reception of these facts by attempting to discuss their meaning, though he could offer explanations of some of them which were satisfactory to himself. He regards the 'Cove' as the remains not of a tomb, but of a shrine, such as stood in the circles at Abury and Arborlowe.

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5. *On the Survival of Palæolithic Conditions in Tasmania and Australia, with Especial Reference to the Modern Use of Unground Stone Implements in West Australia.* *By* Professor E. B. TYLOR, *F.R.S.*

The stone implements from Tasmania, the making and use of which by the natives came under the observation of the colonists during the first half of this century, have a character which may be called quasi-palæolithic. They were fragments or flakes of stone, in no case ground, but edged by chipping on one face only, and trimmed so as to afford a grasp to the hand, no haft of any kind being used. These instruments correspond to some extent with scrapers, &c., belonging to the Drift and Cave periods in Europe, but their general rudeness, and the absence among them of symmetrical double-edged and pointed implements like the flint picks of Old World palæolithic times, place the modern Tasmanians at a distinctly lower stage than the Europeans of the mammoth period. The stone implements found in Tasmania, of which some good collections have now been made, indicate a state of the Stone Age in past times not essentially different from that found in actual existence before the disappearance of the native population. It is necessary to consider these quasi-palæolithic implements, old or new, apart from the few cases of ground stone hatchet-blades fixed in handles, which are now admitted to have been introduced in modern times by Australian natives.

The purpose of the present paper is to offer evidence making it likely that the early Stone Age condition characterising Tasmania extended within no distant period over the whole Australian continent. A native Australian hatchet hafted with gum on a stick-handle was exhibited, lent by Mr. W. Ayshford Sanford, of

Nynehead Court, Somerset, who brought it half a century ago from the Perth district of West Australia. The blade of this instrument, with its unsymmetrical edge formed by chipping along one side of the original flake, is simply indistinguishable from the ordinary Tasmanian form placed beside it. Professor Tylor stated that, unwilling to judge hastily from a single specimen, he had for years been in correspondence with anthropologists in Australia as to the presence there of such implements, and had lately, through communications from the Bishop of Tasmania and Mr. Alexander Morton, of the Hobart Museum, received intelligence that the latter, than whom no one better understands the Tasmanian implement question, has on a late journey to the little-known Murchison district in West Australia, while not meeting with ground stone axes, found the natives using chipped stones quite similar to those used by the Tasmanian aborigines, as shown by photographs sent for comparison. These quasi-palæolithic implements not having yet been dispossessed in this district by the ground stone hatchets, which apparently were introduced from the Torres Straits region, it would seem that this neolithic invasion was of no remote date, and that the vast area including Australia as well as Tasmania may have been till then peopled by tribes surviving at a level of the Stone Age which had not yet risen to that of the remotely ancient European tribes of the Drift gravels and limestone caves. The writer of the paper, while disclaiming any hasty inference, called attention from this point of view to the importance of, and the similarities between, the modern Australioid skulls and the præhistoric skulls of Neanderthal, Spy, Padbaba, &c.

6. *On the Natives of North-West Australia.*
By LOUIS DE ROUGEMONT.

SATURDAY, SEPTEMBER 10.

1. *Report on the North-Western Tribes of Canada.*
See Reports, p. 628.

2. *On the Tarahumare People of Mexico.* *By* A. KRAUSS.

The Tarahumare people occupy an oblong strip of country in the Sierra Madre range, lying approximately between 26° and 29° N. latitude, chiefly on the Western side of the 'Continental Divide,' and at an average altitude of 7,000–8,000 feet. They wander but little from their mountain-gorges, but have been for a century or more in occasional contact with civilised people.

They are short in stature, with regular features, and long, straight, black hair, which is worn long, tied or plaited round the head; hair on the face is rare. Their powers of endurance are remarkable.

They are essentially an agricultural people, growing maize, from which they prepare the crushed and parched meal called *pinoli*, and keeping large herds of goats and black sheep. Cattle are only used for ploughing; but animals which die are occasionally eaten. A fermented liquor, called *teshuin,* is prepared from maize, with pine needles and wild oats.

The men's dress consists of a simple loin cloth secured by a sash, with sandals and a head-cloth; a blanket is carried in cold weather and on journeys. The women wear a woollen skirt.

Hand-made pottery is used for cooking, with occasional utensils of wood, and in agriculture a simple plough, a pointed stick for planting, and a simple hoe. Their only weapons are bows and arrows, of which the points are of hard wood or of agate, and occasionally of old iron. No metal-working is practised, though mineral ores exist in the country.

Their dwellings are of stone and timber, with a well-built storehouse, but in remote districts cave shelters are in use.

The author further described the religious beliefs and social customs of the tribes, and exhibited skulls from a burial cave near the Huajochic River.

3. *On some Rock-Drawings from British Columbia.* *By* C. HILL-TOUT.

4. *On the Myths and Customs of the Musquakie Indians.*
By MARY A. OWEN.

The author discussed the alleged origin and migrations of Musquakies (Red-earth Men); the organisation of their tribe, clans, and families; their courtship and marriage; the social position of the son and the daughter; their training, ideas of ownership, and other rights; initiations and ceremonials, secret societies, magic, &c.

5. *Report on the Ethnological Survey of Canada.*—See Reports, p. 696.

MONDAY, SEPTEMBER 12.

1. *On a Buddhist Image found in an Irish Bog.* *By* Miss A. G. WELD.

This image is of an early Cinghalese type, and was found in 1886 by a labourer at some depth in a bog on the estate of Baltrasna, 15 miles from Kells. It represents the Buddha erect, in the 'preaching' or 'benedictory' attitude.

2. *The Hill Tribes of the Central Indian Hills—their Ethnology, Customs, and Sociology.* *By* WILLIAM CROOKE, *B.A., late Bengal Civil Service, Director Ethnographical Survey, North-Western Provinces and Oudh.*

The author discusses —

(*a*) The ethnological affinities of the Dravidian races, with (1) races exterior to India; (2) the existing population of Northern India.

(*b*) The evidence from anthropometry collected by Mr. Risley, and by the author in his book lately published on 'The Tribes and Castes of the North-Western Provinces and Oudh.'

(*c*) The current theories of the Aryan influence on the existing races; which seems to have been more of a social than of an ethnical character. The paper attempts to controvert the belief that the existing Dravidian tribes are relics of a race driven into the hill tract by the advancing Aryan invaders.

(*d*) The author then considers from a special personal study of these races, the evidence for—(1) the matriarchate and descent through the female; (2) influence of totemism on marriage; (3) group marriage; (4) tree marriage; (5) rules of exogamy; (6) burial rites and the customs of burial in the earth, water burial, cremation.

(*e*) The present social condition and industries of these races are described.

3. *Interim Report on the Anthropology and Natural History of the Torres Straits.*—See Reports, p. 688.

4. *On the Tribes inhabiting the Vicinity of the Mouth of the Wanigela (Kemp Witch) River, New Guinea.* *By* R. E. GUISE.

The author describes the tribes of *Buláa, Kamali, Babaka,* and *Kalo,* detailing their account of their own origin, their laws and customs of birth, marriage, divorce, widowhood, death, and inheritance; their architecture; warfare and weapons (specimens of which were exhibited), hunting, fishing, feasts, planting, foods, diseases and cures, religious beliefs, &c.

5. *The Montzu of Western Sze-chuan.* *By* Mrs. ISABELLA BISHOP.

The author first described her journey, starting from Wei-chau, at the confluence of two branches of the Min, and tracing the Siao-ho, or lesser branch, up to its sources at an altitude of about 11,000 feet on the Isu Kuh Shan range. At Isa Kuh Lao, the last official post of China in that direction, she entered upon the territory of the Issu-su of Somo and lived for some weeks among the Montzu, being lodged either in their houses or on their roofs. She then described the aspect of their villages and their dwellings, their devotion to Lamaistic Buddhism, the power of the Lamas, the ceaseless invocations in family temples, and the numerous external signs of religion, including prayer cylinders made to revolve by water power. She gave an account of their system of government and their marriage and burial customs. Their most noted characteristic was the position accorded to women, who were as unfettered as in England and America, and on an absolute equality with men, possessing legal rights in respect of property, and sharing occupations and amusements with men. She mentioned the freedom of the people from epidemics and many diseases, and the remarkable prevalence of goître. Mrs. Bishop described minutely the dress and ornaments of both sexes, and pointed out certain resemblances to the Lolos of Yun-nan as described by Mr. Colborne Babir. The people had their own language, but it was written in Tibetan characters. The height, size, and stability of their stone dwellings were then touched upon, especially the lofty four-sided stone towers of extreme antiquity which are a feature of all the villages, while the Castle of Somo, the residence of the Ju-ssu, was indicated as of extreme stateliness and grandeur. Mrs. Bishop summed up her detailed account of the Montzu by noting that the characteristic of their physiognomy was that it was European in expression as well as in feature, and recalled the Latin races. The paper was illustrated by lantern slides from photographs taken by the author.

6. *The Swati and Afridi.* *By* Col. Sir THOMAS HOLDICH, *K.C.I.E.*

Our recent campaigns in India have been directed against tribes-people who occupy a district which we have lately cut off from Afghanistan, and which was once known as the province of Roh.

The dominant tribes are Afghans, who have adopted the general designation of Pathan, in common with these Rohillas, who were always Pathans. Afghans now speak the Pathan, or Pushtu, language, and recognise the Pathan civil code; but they recognise no kinship, and claim to be true Ben-i-Israel.

These Afghans objected to being cut off from the rest of Afghanistan by the demarcation of a boundary, and believed that they were to be annexed to India. Hence the recent risings against us.

Explanation of the connection between the Afghans of Swat and the Darani Afghans of Kabul and Kandahar, and short account of the history of the Swatis. Their character, customs, and the manner in which they commenced hostilities against us.

Description of the Afridi—his Rajput origin and independence. The scattered nature of the Afridi clans and want of a recognised head. Afridi customs and blood feuds. Their recognition of the necessity of loyalty to the cause they serve and curious disregard of domestic ties. Their value as soldiers and general intelligence.

Necessity for a study of the frontier people, and their history, in order to draw correct conclusions as to their future status.

TUESDAY, SEPTEMBER 13.

The following Papers were read:—

1. *The Law and Nature of Property among the Peoples of the True Negro Stock. By* Miss MARY H. KINGSLEY.

The geographical distribution of the true Negro stock is a subject worthy of the attention of ethnographers for several reasons. One is that among these peoples we have the most highly developed form of native African culture; another is that in the matters of physical characteristics and mental characteristics the true Negro differs greatly from the better known Bantu stock. A high percentage of error has at present been attained by the failure to recognise these differences, and thereby the work of Sir A. B. Ellis on the true Negro or Bastian on the true Bantu has not yet been given its full scientific value.

The distribution of the true Negro stock is masked in its fringe-regions by the ability of the peoples of this stock to acquire alien languages and culture. In the northern fringe-regions of its distribution it is suffused with Berber culture and Muhamedanism; in its south-eastern and south by Bantu language and culture, with a varying percentage of European adulteration along the sea coast from just south of the River Gambia down to the Rio du Rey and Cameroon. But we have fairly certain tests for the true Negro that are not masked by alien culture and religion.

They are—(*a*) the true Negro does not keep slaves in separate villages from their owners; (*b*) he leaves sanitary public affairs in the hands of Providence; (*c*) he has a regular military organisation with a separate war chief and peace chief; (*d*) among the true Negro the cult of the Law God is far more developed than among the Bantu; (*e*) the true Negro does not have a female God as main ruler of mundane affairs as the Bantu does.

The best region to study the institutions of the true Negro is the region of the Oil Rivers, where he has suffered least from alien adulterations.

Property in West African culture exists in three kinds—(1) ancestral property of the tribe, that connected with the office of the headmanship, called among the true Negroes the Stool, among the Bantu the Fjort; (2) family property, in which every member of the family has a certain share, to which every member of the family has to contribute, and on which every member has a claim; (3) private property, that which is acquired or made by a man or woman by their personal exertion over and above that made by them in co-operation with other members of their family, which is family property, and that gained by gifts and that made in trade by the exertion of superior trading ability.

Each of these kinds of property is equally sacred in the eye of Native Law. The only kind that can become another kind of property is the private. This constantly merges into family property on the death of its individual owner. Stool property and family property remain of their kind for ever and cannot be alienated, though liable with all three kinds to meet debt.

Wealth is divisible into—(*a*) the means by which property can be acquired and developed; to this division belong wives and slaves; (*b*) property in power over market rights, utensils, canoes, arms, furniture, trade goods, &c. It is in the capacity to command these things that the wealth of a true Negro—man or woman—consists, and it is by slaves and by relationship with influential people that he can attain to it.

Property is guarded by and exists under the law which is in the hearts of the people themselves. This is represented by the cult of the Law God—the so-called secret society of the district—Oru, Purroh, Egbo, Belli, &c., and by the influence of religion. For details of the manner in which these powers conjointly act in preserving property, see a lecture by the author on 'African Religion and Law' given for the Hibbert Trustees and published in the 'National Review' for September, 1897.

2. *The Native Secret Societies of the West Coast of Africa.*

By H. P. FitzGerald Marriott.

Spread throughout West Africa from the Gambia to the Kongo are various native secret societies, some well known by name, others very secret and powerful, and known of but by few white men, which must not be confused with fetich customs and priests. These societies contain the religious and social principles of the people, and administer justice according to native law and custom. The kings, princes, chiefs, and great men belong to these organisations, and by their means sustain their own power. Some of them are merely temporary, such as the lesser Purroh of certain parts of Sierra Leone, of which white men speak; others again are ancient tribal institutions, such as the secret religious or state Purroh with its grand council, of which most people are unaware. A man may live forty years on the coast and never hear of *Kofong*, that powerful, mystic society which controls the Limba nation, as was not long ago evinced to the author by a gentleman who, knowing the coast well, called on him in town and brought with him a native of another Sierra Leone district. The white man denied its existence, but after a few moments the author extracted from the native that there was such a society as *Kofṓ*, and that in another part it was called *Kofṓoi*, and in Mendi he thought that it was *Jṓosŏi*; the author said that it was the same, and at the same time made certain Kofong signs, which he understood (as was evident from his expression), and he acknowledged that he belonged to it, but had not taken its highest forms; all of which rather put the white friend out of countenance. But even this native knew little of the true inner Kofong, or of any other societies elsewhere, such as on the Gold Coast, and others like the Egbo in the Niger. Nearly all these societies oblige their initiates to undergo circumcision, if this rite has not been previously performed in youth or childhood; the female societies are almost solely for that purpose, amongst them the Bondo of Sierra Leone is perhaps the best known by name.

The science of life and death is taught in the highest of these societies, and even hinted at in the inferior. Mohammedan influence is seen not only by the personal association of the latter, but by the knots that are used as charms (conf. *Koran* 113 súra), both by some of these societies, as well as by individuals. Fetichism must not be confused with these societies. Spirit worship perhaps may be associated with them; but a mystic religion and belief in one God, a Creator, from whom springs all life, and to whom death is but in some sort a return, is, I believe, the very inner secret of secrets; more they do not teach; they dabble in a low form of magic, or devil-worship (black magic in more than one sense), and they uphold the ancient usages of the country, and the balance of the powers that be. The names and varieties of these societies are numerous. Those nearest to each other are generally on good terms, though distinct; and all could be more or less connected, as is proved by the safety with which a Mohammedan may advance near a religious Purroh procession, or even Purroh bush in safety; with regard to Purroh and the Mohammedan, this may be on account of the rite of circumcision. In various instances the Government could employ these societies to carry out its ends, and by means of methods to which the natives are accustomed could gradually habituate them to British law and order.

3. *On the Natives of the Niger Delta.* *By* M. le Comte Charles de Cardi.

The Paper gives some account of the early navigators who visited Western Africa; of a theory of the origin of the Benin people, and of many of their customs; of *Ju-Juism* in the Delta, with some account of devil huts; of the long Ju-Ju of the Delta, its uses and abuses; of defilement and purification, human sacrifices and 'father-making,' ordeals, poisoners, and methods of poisoning; and concludes with an estimate of the capabilities and future of the West African.

4. *Ancient Works of Art from Benin City.* *By* C. H. READ, *F.S.A.*

Benin is an inland city, situated about 70 miles up the river of the same name in the Niger district. Its position near this great waterway has brought it into contact with influences from the north by means of the great trade routes which diverge towards the north from such trading centres as, *e.g.*, Timbuktu. It was thus possible that in Benin might be found some relics of the ancient civilisations of the Mediterranean; an opinion held by the late Sir Richard Burton. Relations with Abyssinia are founded on the journey of a Franciscan friar from the neighbourhood of Benin to Christian Ethiopia in the fourteenth century, and some corroboration is found in the Benin tradition that the king was subject to a powerful prince far to the east.

In the hope of finding evidence of these traditions in the loot that came from Benin Mr. Read had made representations to the Government, with the result that a large collection of ancient examples of Benin art had been secured for the British Museum, though it could scarcely be said that they had any direct bearing on the relations of Benin with either the extreme north of Africa or the east.

A document of great interest bearing on their origin was a report of Sir Ralph Moor, giving the account of a palaver with seven natives—the Court historian, three Ju-ju men, the master smith, master wood carver, and the master ivory carver. After giving the list of the kings of Benin, twenty-three in all, these authorities recited the great events that had taken place in each reign. From this account it appears that the white men first came in the time of King Esige, the tenth in the list, and one of them, named Ahammangiwa, made the plaques and brasswork for the king. Assuming an average reign of twenty to twenty-five years for each of the kings, this would bring the time of Esige to about 300 years ago—a date that would correspond very well with the date of the European costumes shown in the plaques. It was somewhat difficult to obtain the average duration of the reign of an African potentate, but taking the reigns of Chinese and Japanese emperors for 300 years, the average duration of these was twenty-seven and twenty years respectively. Following these lines, it would seem that the Benin tradition as given in Sir Ralph Moor's report was very likely to be accurate.

5. *On the Languages of Kavirondo.* *By* C. W. HOBLEY, *F.R.G.S.*

The paper introduced a number of vocabularies collected by the author, reference copies of which have been deposited in the library of the Anthropological Institute until circumstances permit of their publication in full.

6. *On Egypt under the First Three Dynasties, in the Light of Recent Discoveries.* *By* Professor W. M. FLINDERS PETRIE.

7. *On the Folk-lore of the Outer Hebrides.* *By* Miss A. GOODRICH-FREER.

The folk-lore of the Outer Hebrides has a degree of interest which justifies the labour and inconvenience attendant on the conditions under which alone its collection is possible. The islanders, among whom the author has spent many months and gathered stories in the strangest surroundings, are courteous always, but reticent, proud, and suspicious, as well they may be, of English or even of Scot; and yet with an almost childlike friendliness for those who come among them, speaking their own tongue, and of like blood and passions with themselves. But kind and friendly as the islanders have always been, the author's attempts would have had comparatively small results but for help received from the Rev. Allan Macdonald, priest of Eriskay, whose lifelong knowledge of the islanders is unrivalled.

Contact with modern civilisation and the consequent decay of native industries and modes of life have proved here, as elsewhere, fatal to folk-lore; and even the very language in which the older life is crystallised is neglected by the School Board and despised by the rising generation.

Yet in the old days every act of life seems to have had its associated tradition: the lighting of the fire, the milking of the cows, the driving them home, the roosting of the poultry, the watching of the cattle, the realisation of the changing seasons, the baking of bread, the catching of fish, every detail of weaving and dyeing and fulling, all had their special rhyme, or song, or story. In the long winter evenings the time was passed in weaving heather ropes or making nets, while stories were told by recognised *scalds,* the literary descendants of the ballad-makers of the Vikings who occupied these islands. Some of these stories are of great length, and must have occupied many evenings in narration. Some are of Ossianic origin. Here, as elsewhere, stories such as 'Cinderella' and 'The Sleeping Beauty' are related in terms appropriate to the locality. Many of the songs have their special tunes, some of which the author has secured.

Every member of the scant fauna, and every phase of the culture of the land or of the sea, has its legend and its song. The undertone of half the legends is the friendship and the kindliness of the sea—all are safe in the boat, be it but a few yards from shore.

Besides the innumerable and often unique superstitions—midsummer fires, salutations to the sun, and Hallowe'en divinations—the author attaches a peculiar value to the ancient hymns, the quaint apocryphal stories, the prayers for all sorts of occasions, the old catechisms and rosaries, the legends of St. Columba and his followers, of St. Patrick and St. Bridget, the charms, spells, and divinations, with their odd mixture of Paganism and Christianity, as these, perhaps more certainly than the rest, are becoming every day more difficult to recover.

The author illustrated various archaic agricultural and domestic implements and the methods of using them, and exhibited specimens of home-made cloth, of the vegetable dyes used, of articles made of heather and 'bent,' and of charms and cures for disease.

WEDNESDAY, SEPTEMBER 14.

The following Reports and Papers were read:—

1. *Report on the Lake Village at Glastonbury.*—See Reports, p. 694.

2. *On the Place of the Lake Village of Glastonbury in British Archæology.*

By ARTHUR J. EVANS, *F.S.A.*

3. *On Traces of Terramare Settlements in Modern Italian Towns.*

By Professor W. M. FLINDERS PETRIE, *D.C.L.*

4. *On the Megalithic Monuments of Dartmoor.* *By* P. F. S. AMERY.

5. *Report on the Silchester Excavations.*—See Reports, p. 689.

6. *On Walled-up Skeletons.* *By* Miss NINA LAYARD.

7. *Report on the Ethnographical Survey of the United Kingdom.* See Reports, p. 712

8. *On Traces of Early Kentish Migrations.* *By* T. W. SHORE, *F.G.S.*

The author first draws attention to the various names by which the Jutes of Kent were known to early chroniclers and writers, and to authorities which show that the Jutes were closely allied to, or identical with, the Northern Goths. From the evidence of early place names, such as Goda (for a Goth), and Geats or Geatas (for Jutes), frequently used as descriptive names of early Kentish settlers, in addition to purely Kentish names compounded of the names Kent, or Ken, and from the circumstance that Kent, unlike the other chief Anglo-Saxon States, had no Hinterland, he infers that the migrations of Kentish people must have led them to settle in unoccupied land of the other kingdoms, and identifies such early Kentish colonies by such place names, under their present or a more ancient form; by survival of customs of land tenure, &c., analogous to those of Kent; by other place names derived from the Jutish hero Hengest, which formerly existed in the same localities, and still survive in some instances in a modified form; and by survivals of *gavelkind* and kindred customs in many similar places, and refers to the possession of land in Herefordshire and Yorkshire by the early Archbishops of Canterbury, and by the first Archbishop of York, who also came from Kent.

The causes which led to migrations of Kentish people he considers to be the pressure of population at home, the openings for colonisation which arose from the marriages of Kentish princesses with sovereigns and princes of other States, the necessity for military colonists on the frontiers of the expanding States, and zeal for Christian missionary work, of which Kent was the centre.

The author collected evidence of Kentish colonies in (1) *the Isle of Wight* and in *S. Hampshire*,[1] probably the earliest migration from Kent, which is indicated by the similarity of place names. This settlement probably extended into *Dorset*, where *gavelkind* long prevailed at Wareham.

(2) *S. W. Herefordshire* (Archenfield district): Jutish and Kentish place names, such as Kentchurch; *gavelkind* of the Kentish type (as distinct from the Welsh type);[2] and a number of other Kentish customs (which survived until the sixteenth century).

(3) *Yorkshire*: gavelkind existed on the lands which formed the Fee of St. Peter's, York, *e.g.* Knaresborough; in the honour of Richmond, where the inferior tenants enjoyed some of the same privileges as in Kent. Place names in Richmondshire, *e.g.* the Swale River. The alternative name of Gillingshire for this district arose from the monastery of Gilling, founded by the grand-daughter of the first Christian King of Kent.

(4) *Nottinghamshire* and *Leicestershire*: Kentish and Jutish place names, also *gavelkind.* The earliest form of the name of Leicestershire, viz. *Læthecæster-scir*, which occurs in A.D. 679, before the earliest Danish invasion, may point to the division of the county into *laths*, as in Kent; the present *Hundred* names of the county were probably ancient *Lath* names. These hundreds were divided.[3]

(5) *Westmoreland*: Kentish names like Kentdale, Kendal, and Kentmere, and the survival among the Kendal tenants of some of the special privileges of *gavel-*

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[1] T. W. Shore, *Antiquary*, March 1890.

[2] Glanville (*Temp. Henry II.*) says that *gavelkind* tenure was only recognised in the Law Courts of the twelfth century in those places where it could be proved, as in Kent, that the lands always had been divided.

[3] J. H. Round, *Feudal England.*

kind tenants in Kent, especially the rare one of freedom from the common law of distress.

(6) *Devon*: The name Kenn and others (written in Domesday Book, like Kent itself, as *Chent*), near Exeter, and partible inheritance of the Kentish kind in the City of Exeter.

(7) *Somerset*: Kentish and Jutish names along the coast, especially the Hengest place names.

(8) *Worcestershire, Gloucestershire* and *Shropshire*: Hengest place names in the valley of the Severn, groups of other Kentish and Jutish place names.

(9) The *Thames* Valley, as a channel for migration from Kent. Kentish *gavelkind* among the old manors, which bounded ancient London on the north, and the survival of *Borough English*, which was closely allied to it, in most of the manors which bounded London on the south and west; the Hundred names of (Kintbury, in) the Kennet Valley; names such as Kentish Town, and Gatenesheale (for Vauxhall), Kennington, Kensington, Twicanham (Twickenham), Kent Town near Molesey, Kenton (Kempton); Hinksey, near Abingdon, the Hengestsie of Saxon charters, and two other Hengest names with Gode, Ken and Geat, or Yeat; names occur near the river above Oxford, the highest being Kempsford, the Chenemeresford of Domesday Book; partible inheritance (in Domesday) at Hochenarton, a place with a Kentish name (Hook Norton) in Oxfordshire.

9. *On the Folk-lore of Guernsey.* *By* the late Mrs. MURRAY AYNSLEY.

The prevalent belief in witchcraft and demoniacal possession was illustrated by the stories of Belier Boeuf and the Roussels; of the resuscitation of one Jean Robin, and of another case of exorcism by D'Orlean; and a local legend of St. George and St. Patrick was given.

10. *On some Myths and Fancies of Insect Life.*
By S. CLEMENT SOUTHAM.

The author discussed and illustrated the traditions and cults attaching to bees as messengers of the gods, spiders in folklore and folk medicine, ants, crickets, ladybirds, and beetles.

11. *On the Exploration of Two Caves at Uphill, Weston-super-Mare, containing Remains of Pleistocene Mammalia. By the late* EDWARD WILSON, *F.G.S.* See p. 867.

[Communicated by HERBERT BOLTON, F.R.S.E.]

SECTION K.—BOTANY.

President of the Section.—F. O. Bower, D.Sc., F.R.S., Regius Professor of Botany in the University of Glasgow.

THURSDAY, SEPTEMBER 8.

The President delivered the following Address:—

Shortly before we met last year in the hospitable Dominion of Canada, two biologists, whose work relates to the questions I propose to discuss to-day, passed away. In both cases their services to science had received honourable recognition in this country. Johannes Japetus Smith Steenstrup, who had been for more than thirty years a foreign member of the Royal Society, died June 20, 1897, at the advanced age of eighty-four; Julius von Sachs, also a foreign member of the Royal Society, died May 29, 1897, aged sixty-five.

The former of these, a zoologist, was probably best known in this country for his work on 'Alternation of Generations,' a translation of which was published by the Ray Society in 1845. The title-page describes the phenomenon as 'a peculiar form of fostering the young in the lower classes of animals.' Botanists should remember that this term 'alternation,' which they often use in a sense peculiarly their own, was originally applied to the course of development in certain animals by Chamisso in 1819. The first general statement of the subject from the zoological side was by Steenstrup in the work already named; even there no mention is made of such phenomena in plants, until the concluding paragraph, where there is an allusion in very general terms to the course of events in the life of seed-bearing plants. But when we remember that it was only in 1848 that Suminski discovered the antheridia and archegonia borne upon the prothallus of a Fern, we see plainly that Steenstrup could not have used the term 'alternation' in the sense in which it is now generally applied to plants. The interest for us as botanists will therefore be that Steenstrup suggested in his work on alternation in animals how in the life of plants successive phases exist, and that these are comparable to those which he described in many animals.

The work of Sachs, on the other hand, has influenced every one of us. Some, including myself, have had the great advantage of his direct personal guidance; all must have derived pleasure as well as profit from his writings. I shall not here attempt any general summary of the achievements of this great man, for that has been done efficiently by the scientific press at large. I shall merely allude to one feature of his work—viz. the style of its presentment to the reader. He was always clear, usually concise. He was, in addition to his power as an investigator, a master with the pencil, as well as with the pen. It was this combination of qualities which made him the great text-book writer of his time. Never perhaps has a volume more fairly reflected the position of a science at the moment of its publication than did that of Sachs. It resembles the work of a snap-shot camera, and, like any instantaneous photograph of life in motion, it has fixed and perpetuated awkward positions. The morphological system of the time was stiff and unpromising; the text-book accurately depicted this, but it did not suggest or anticipate future developments; it did not bear the softened image of a longer exposure; it presents to us the angular attitude of a moment.

The powers of Sachs as a writer found their best scope in his 'History of Botany,' a work which will always retain its value as a masterly exposition of the results of very wide reading, arranged with a literary skill which is unfortunately rare among scientific men. I lay stress upon this power of Sachs as a writer, apart from his record as an investigator, because he was strong where so many of us are weak. The truth is that little effort is made by men of science to use a concise and transparent style; for the most part we write by the aid of such instincts as Nature has given us; few cultivate composition. But it should, I think, be impressed upon the young aspirant that, when he writes, it is one of his first duties to consider his readers' convenience; he must use all endeavours to convey forcibly the result of his inquiry, but to make the least possible demand upon the patience of his readers. I should like to see certain papers selected as models of construction, to be studied as such by all candidates for our higher degrees; we should naturally include in the list those of the best masters of style in foreign languages, and among them would rank the late Julius von Sachs.

THREE PHASES OF MORPHOLOGICAL STUDY.

It will be in your memory that the Address of last year's Sectional President was largely devoted to branches of our science which touch the material and economic interests of man. It was pointed out to us how certain fungal diseases diminish agricultural profits to an extent which may be estimated in millions of pounds yearly. Beneficent microbes were also mentioned, such as those which govern the aroma and maturing of butter and cheese; these and many others, the study of which lies properly within the province of botany, affect not only the health, but, at the most varied points, the comfort and prosperity of mankind.

It is unnecessary for me to dwell further upon these points, or to urge again the utilitarian argument for the proper support of botany. I propose, on the other hand, to invite your attention this morning to the Morphology of Plants. This is a department of science pure and simple. The results which it brings have not, and cannot be expected to have, any money value in the markets of the world. The present time is one of unusual bustle and change in morphology, consequent upon the discovery of new facts and the introduction of new methods. The development of the study may be divided into three periods, we ourselves standing upon the threshold of the third. The earliest phase was that of description and delineation of what might be observed of the mature form of plants; this includes the work of the herbalists and of the earlier systematists, who thus furnished the basis for classification. It is true that the mere description was enriched at times by comparisons made, but these often took a capricious form, as is shown by the many curious allusions which still survive in the nomenclature. Erasmus Darwin satirised the imaginative comparisons indulged in by early writers in his 'Loves of the Plants;' an instance of this is seen in his lines referring to the legendary organism, half animal, half plant, suggested by the peculiar form of *Dicksonia* (*Cibotium*) *Barometz*:—

> 'Cradled in snow and fann'd by arctic air
> Shines, gentle Barometz, thy golden hair.
> Rooted in earth each cloven hoof descends,
> And round and round her flexile neck she bends;
> Crops the gray coral moss, and hoary thyme,
> Or laps with rosy tongue the melting rime.
> Eyes with mute tenderness her distant dam,
> Or seems to bleat, a *Vegetable Lamb*.'

The tendency to comparison thus already perceptible asserted itself strongly in the next phase of our study, to which it gave its character. And now the need arose for observing development; this was initiated by Schleiden, and carried to a triumphant climax by Hofmeister. Passing from the hands of these pre-Darwinian to those of post-Darwinian writers, the comparisons, while remaining virtually the same, received a new significance. Observers now pushed their inquiries into the details of anatomical structure and development, and in many cases attached an importance beyond what is justifiable to minute similarities or differences of cell-cleavage. Thus what might be called 'cellular morphology' became a feature of the period. It has, however, been in a measure discredited by the excessive zeal of some of its votaries, who drew large conclusions from slight facts; a salient example of this is furnished by studies concerning segmentation of the ovum. But we must not assume that because it has been pursued indiscreetly the study of segmentation is effete; there is still scope for valuable observation, which will bear a reasonable burden of argument; though conclusions from such a source must be compared with those derived from other data, and a due estimate of them must be made accordingly.

Morphology has lately passed to a third stage—that of experiment—with a view to ascertaining the effect of external agencies in determining form, and the limits of variability under varied circumstances. Development of itself shows only how a part originates; it does not demonstrate what it is, nor what it may become under special conditions. This new and growing phase of experimental morphology, together with comparison from the point of view of descent, now tends to supersede the formal morphology of the second period, which in many minds implied or assumed ideal types or creative plans. It has become a general view that the facts of morphology are but the stereotyped facts of physiology, form being determined by function, but under the check of heredity. This third experimental phase of the study of plant-form is directed, as it were, to the very setting of the types, before the stereotype plate is cast. We watch Nature's compositor at work, but we also ascertain that the plate itself, after it is cast, is much more plastic than some of us had thought.

These three phases of morphological inquiry have naturally overlapped one another; we recognise, however, that first description, then formal comparison, and now experiment, have been the leading features in morphological investigation during these successive periods.

HOMOLOGY.

The ideal aimed at in the study of the morphology of plants is to trace their real relationships and mode of origin, on the basis of the widest observation—in short, to reconstruct the evolutionary tree. In order to make comparison possible, or at least manageable, a terminology is necessary, and this not only of the plants themselves, but also of their parts. We may for the moment leave on one side that summing up of morphological opinion represented by the systematic arrangement of plants in a taxonomic system. I propose to-day to discuss not the classification of plants, but the classification of the parts of plants, their grouping according to their *homology*. And here I use a word which is probably explained to every class of elementary students; it is one of those terms a meaning of which is indeed revealed to the babes of the science, while those who teach are not at one as to its definition. We need not enter now into the various opinions which have been held on this point, nor need we make any antiquarian research into the introduction or early use of the word *homology*; it will suffice to state that it was already firmly established in the science before views as to descent gave it any intelligible meaning. We speak of the homologies recognised by Hofmeister, but it should be remembered that their great discoverer did not put an evolutionary interpretation upon them. Sachs points out in his history how 'the theory of descent had only to accept what genetic morphology had already brought to view.' Nevertheless, much remained ingrained in the very texture of the science which was incompatible with evolutionary thought. This was so even in the text-book of Sachs itself. The categories of root, stem, leaf, and hair are there laid down, and the parts classed under these several heads were held to be *homologous.* In their definition all those characters which refer to function were put aside, the definitions relating to origin and relative position; the reproductive organs were grouped with the rest, with the result that these parts were described as bearing a varying morphological value. But this purely formal morphology is now dead; it long survived a mere passive belief in evolutionary views, but their active practice has strangled it. The first step towards emancipation was the recognition of sporangia as parts *sui generis.* Eichler, agreeing with Braun and Strasburger, found it 'highly probable according to the theory of descent' that such a structure as the ovule has universally the same morphological dignity. It remained for Goebel to make the general statement that sporangia stand in a category by themselves, and are probably not the result of modification of any vegetative part. It was in this way that the phylogenetic factor was first asserted as bearing on a question of importance in the morphology of plants. Adherents of descent no longer passively accepted the direct results of investigation; they began actively to check and control the interpretation of them; but this position was not attained till more than twenty years after the publication of Darwin's 'Origin of Species.' Since then, however, views as to descent have taken an increasingly important place in the province of morphology, till at the present moment a far-reaching comparison of allied forms, assisted by experiment, is the most potent instrument in the hands of the morphologist.

But various writers admit in varying degree this factor of comparison as controlling other considerations. There is indeed a wide range of difference on this point. I will cite only two extreme views. On the one hand is the view of Strasburger, which he enunciated so early as 1872. The enthusiasm for evolution in the Jena school found its botanical expression in the aphorism, 'The highest problem of morphology is to explain the form of plants, but this problem can only be solved genealogically.' This statement is repeated in a more definite form in Strasburger's text-book: 'Phylogeny is thus the only real basis for morphology.'

At the other extreme is the method of physiological organography put forward by Sachs in his Lectures. I am aware that he subsequently modified his views; I merely quote the system which he propounded in 1882, as being the antithesis to that of Strasburger. For in the physiological organography descent is hardly taken into account at all; parts which are plainly of distinct origin by descent are classed together. This organography of Sachs, though introduced with all its author's charm of style, never convinced the botanical world, for it treated plants too much as the creatures of present circumstance. It may be taken as illustrating the extreme reactionary swing of the pendulum from the non-physiological attitude of the formal morphologists; a protest against the exclusion of function from the morphological arena. The protest was salutary, but its form was extravagant.

Let us now consider whither 'phylogeny, as the only real basis of morphology,' may lead us. Let us take as our provisional view that *homology* in the strictest sense implies repetition of individual parts, in successive generations, just as the hand of the child repeats in position and qualities the hand of the mother. Though among seed-bearing plants, for instance, this repetition may apply for the plant-body as a whole, it will be at once apparent that such repetition as regards the individual is found in comparatively few cases in plants. The continued embryology of all the higher forms, the indefinite number of the parts successively produced, and the variety in detail of their arrangement show that in the strictest sense repetition of individual parts cannot be traced. In a pan of seedlings of the Sunflower, raised from seed of the same parent, the cotyledons in all cases may be regarded as homologous in the strictest sense, as they correspond in origin, number, position, and form to like parts in the parent. In a similar way the first root of the seedling appears to be individually identical with the first root of the parent, or of any other seedling of the batch. In those plants in which a foot or suspensor is present occupying a constant position with regard to the parts of the embryo, it will not be doubted that within near lines of affinity the foot in any one specimen corresponds to that of any other. The exact repetition which is thus found to exist may be regarded as the most complete type of homology.

Starting from this repetition of individual parts in plants nearly related, there is a divergence by gradual steps in two directions: Firstly, in the individual plant, where the later formed parts may assume forms and positions which may even raise a question of their essential correspondence. Thus in the batch of Sunflower seedlings there may be a varying number of leaves, with varying transition from the decussate to the alternate arrangement, intervening between the cotyledons and the capitulum. As they vary in number and position these cannot in the strictest sense be accepted as individually comparable, each to each by descent—the lineal representatives of like individual parts in the parent. The lateral roots also, though all essentially similar, do not correspond each to each, either in number or in position.

Again, to go a step further, a Fern prothallus produces antheridia and archegonia; their number and position are not uniform; by conditions of culture we have them under control, and can induce antheridia only, or we can induce a formation of archegonia upon the upper surface, where they are usually absent. Plainly these cannot be held severally as the exact representatives of like individual parts in a previous generation. Another exceptional but most interesting case is that of *Aspidium anomalum*, Hk. and Arn., which Sir William Hooker remarks is possibly an abnormal form of *Aspidium* (Polyst.) *aculeatum*, Sw. In this Fern the sori, instead of being all on the lower surface, as in allied Ferns, are often upon the upper surface of the leaf. There is no sign of tortion to explain the anomaly, while the sori themselves present no structural peculiarity except that they are sometimes quite destitute of indusium. There has doubtless been a transfer of developmental capability from the usual position of the sori to the anomalous one. In case of such transfers as these we do not doubt that the parts in question are to be ranked as comparable to those in the normal position; we contemplate here, as in the case of the Sunflower leaves, an essential correspondence, but not an individual repetition of the parts, and we learn that parts thus essentially corresponding to one another may be transferred to unusual positions.

Secondly, in plants more or less nearly related, those which are less akin may show so slight a similarity in detail that again questions of the essential correspondence of the parts may arise. Within nearer circles of affinity these questions will affect only the appendages of minor importance, which show less constancy of occurrence and arrangement, such as emergences and hairs; but in case of plants less nearly akin the degree of correspondence of the larger members may become a matter of debate. Take, for instance, the three great phyla of living Pteridophytes, the Ferns, Equiseta, and Lycopods. While the sporophyte as a whole in each of these may be accepted as homologous by descent with that of the others, the question as to the true correspondence by descent of the leaves must still be open for discussion. It is a tenable view that the three phyla arose separately from a non-foliar ancestry, and that the assumption of a foliar development, having in each case a different habit, and a different relation to the sporangia, led to the distinctiveness of the three stocks. Opinion on the point of homology by descent of the leaves of these Pteridophyta must at present remain in suspense; but the case is different with the leaf of Pteridophytes as compared with the leaf of Bryophytes: unless the whole morphological system of the time be in error, we shall be right in maintaining that these foliar developments have been distinct in origin from the first.

Now all the foliar parts above quoted would in a system of merely formal morphology fall into the category of 'leaves.' But if phylogeny be accepted as the only real basis of morphology, we must be prepared to split up the category based on mere time, place, and mode of origin, and to recognise in some cases repetition of individual parts; in others essential correspondence, but not individual repetition, owing sometimes to transfer of developmental capability; in other cases again, a possibility of distinct origin by descent not actually proved; and lastly a reasonable certainty of distinct origin. The practical question for the morphologist is, having recognised these facts for himself, how is the matter to be best made intelligible to others?

A reconsideration of the term 'homology' will thus be necessary: is it to be applied equally to such parts as are connected by lineal descent, and also to those which we have good reason to believe have resulted from parallel development in quite distinct phyla? Or, to put a finer point upon our inquiry, are we to distinguish in any way the cases of 'individual repetition' from those of 'essential correspondence?' In the latter case I think no good end would be served at present by accentuating this distinction by terms: the steps of divergence are so slight and gradual. None the less should it be clearly borne in mind that comparisons of parts commonly ranked as homologous in the plant body are based on a less complete individual correspondence than that of parts usually compared in the animal body.

But the case is different in dealing with parallel developments, and some doubt arises whether parts which probably, or it may be certainly, have arisen by separate evolutionary sequence in distinct phyla are to be classed as homologous in the same sense as those directly related by descent. This question was long ago taken up on the zoological side by Professor Ray Lankester, and it was shown that the old word 'homology' covered two things recognised as distinct from the point of view of descent. He defined as *homogenous* 'structures which are genetically related, in so far as they have a single representative in a common ancestor.' On the other hand, 'when identical or nearly similar forces or environments act on two or more parts of an organism which are exactly or nearly alike: further, if, instead of similar parts in the same organism, we suppose the same forces to act on parts in two organisms, which parts are exactly or nearly alike, and sometimes homogenetic, the resulting correspondences called forth in the several parts in the two organisms will be nearly or exactly alike. . . . I propose to call this kind of agreement *homóplasis* or homóplasy.' Now this distinction of terms requires also to be observed in plant-morphology, and I am surprised that it has never yet been adopted by botanists, though we have long recognised cases of parallel development. I do not propose now to spend time in assigning these terms to familiar cases: but to take the examples already cited, the leaf of a Fern would be homoplastic, though not homogenetic with the leaf of a Moss; or, taking examples from plants more nearly akin, it would appear possible that the leaves of the three distinct phyla of living Pteridophytes show merely homoplasy, not a true homogeny.

The successive foliage leaves of most plants are assumed in the individual to be the result of a mere repetition of development. But it is quite a possible view that in the plant-body (as is contemplated in the animal in those cases of 'serial homology' which Lankester recognises as homoplastic) homoplasy may have had a place. We must inquire whether all those structures which we designate 'leaves' have actually been the result of a development identical, or at least essentially similar as regards their origin in the race. The problem is, given a plant with numerous leaves of various form and function, to unravel the real story of their evolution. Two distinct factors may be contemplated as possibly occurring even in the individual, viz.:

1. *Homogeny* of genetically related parts, with or without repetition of the parts formed.

2. *Homoplasy*, an origin of two or more distinct categories of parts, not genetically related, on the same organism.

Working upon either of these, and thus complicating the problem by obliterating such distinctions as may have existed at first, may be the phenomenon of *metamorphosis*. This has lately received its evolutionary definition at the hands of Professor Goebel, as restricted to those cases where there has been an obvious change of function. We see how change of function accounts for various forms of leaf in certain cases; but it does not follow that all leaf-forms on the same plant were so produced, by metamorphosis of a single original type.

The Lycopodineæ are particularly interesting in illustration of this point. It appears probable that *Phylloglossum* is a more primitive type than other living Lycopods; it has two kinds of leaf, the protophylls borne in irregular number and arrangement on the protocorm, and the sporophylls of different form from these, and arranged regularly on the strobilus: commonly there are no intermediate steps between them. This condition in a plant, which on general grounds of comparison we believe to be primitive, is certainly interesting, and we shall ask whether the two types of leaf have not arisen by distinct evolutionary sequence? In the genus *Lycopodium* there are certain species, such as *L. Selago,* which show alternately sterile and fertile zones; examining the limits of the sterile zones, we find at the base of each leaf an atrophied sporangium, similar in position to that borne by a sporophyll. When we compare this condition with that of *Phylloglossum* it appears probable that the successive zones are the result of a metamorphosis of a strobilus, which had a continuous apical growth, and unlimited repetition of sporophylls, but that some of these suffered atrophy of their sporangia, with the correlative effect of a larger vegetative development. A differentiation of the strobilus thus results in the plant as we see it, a production of foliage leaves by sterilisation of sporophylls. Recognising this, some may suggest that the protophylls originated in the same way. It is possible that they did; but it is equally possible, and, in view of the peculiar case of *Phylloglossum,* I think more probable, that in these plants we have an example of homoplastic development of parts distinct as to descent, while the limits of the two still evident in *Phylloglossum* became obliterated in the more complex case of *Lycopodium.* The proof of the point will be difficult or even impossible, but the eyes of botanists should certainly be open to recognise such individual homoplasy, should it occur, and to inquire whether it has really had a place in plant-development.

Returning now to homoplastic development in distinct groups of plants, the morphology of the *foot* provides interesting material for comparison, and especially so since there is no question of repetition here; for the comparison is between parts of which only one appears on each individual plant.

The term foot has been applied to that part of the embryo in Pteridophyta which serves to connect it physiologically with the prothallus; the term has also been used for the base of the seta in Bryophytes. Parts performing a similar function, but not referable as in other Phanerogams to the metamorphosis of cotyledons, are also found in *Gnetum* and *Welwitschia.*

In the Bryophyta what is usually called the foot is no definitely specialised structure; it is merely the absorbent base of the seta. It would appear probable that in the Bryophyta a true homogeny holds in all cases, as the requirement for it will have been uniform; and its basal position is also uniform, though some difference of detail does appear in the relation of this absorbing body to the first segmentations of the embryo.

In the Pteridophyta it is exceedingly difficult to be sure of the correspondence by descent of the foot in distinct types, and indeed it should not be assumed that a specialised absorbent organ was always present, though general surface-absorption will naturally have taken place in all archegoniate embryos; indeed, the condition of some upright embryos is such that a foot would never have been described, were it not for comparison with other types. In *Equisetum, Isoëtes, Botrychium*—all forms without a suspensor, and with an upright growing embryo—the hypobasal half of the embryo, with or without a root, is absorbent as in the Bryophyta, and is described as a foot; it is quite possible to see in them the continuation of a primitive absorbent organ. This may also be the case in the Marattiaceæ, and it is specially noted by Campbell that 'in *Marattia* all the superficial cells of the central region become enlarged and act as absorbent cells for the nourishment of the embryo.' From such types we may imagine the more specialised foot of the Leptosporangiate Ferns to have been derived by a localisation of the absorbent function on one side only, which would be a natural consequence of the embryo taking the prone, in place of the vertical position.

A different course of events probably occurred in the Lycopodineæ. I am disposed to think that here the suspensor represents nothing more than a specialised part of the primitive absorbent organ; this seems to be indicated by the details as shown in Treub's figures of *L. cernuum* and *L. Phlegmaria,* in which the suspensor is continuous with the foot. But what is, then, the 'foot' of *Selaginella,* which is quite apart from the suspensor, the root intervening? On this point I think we obtain light from *Welwitschia* and *Gnetum,* for in these we see an absorptive organ formed at a comparatively late period; and it corresponds in position and function, though not in time of origin or details of structure, with that of *Selaginella*. I conclude that the 'foot' of *Selaginella* is probably a later formation, not comparable as regards descent either with the foot of *Lycopodium* or with the 'feeder' of *Welwitschia* or *Gnetum*. The latter are plainly of recent independent origin as comparison shows, and their actual position is defined according to the position of the seed in germination. Probably, then, there is homoplasy in such cases, not true homogeny.

Similarly with such structures as the pinnæ, stipules, indusium, corona, and still more so with such inconstant bodies as emergences and hairs; when we speak of the 'homologies' of these parts it is rarely the *homogeny*, or identity by descent, which we mean to express; usually it is only *homoplasy*, a comparison of parts similar it may be in form and position, or even in development and function, though not shown to be comparable by descent.

ALTERNATION.

But the questions above discussed are mere matters of detail, compared with that great enigma of the alternation of generations in green plants, or of alternation at large. This is, after all, a question of degree of homology, not now of the parts only, but of the whole plant or 'generation.' How this greatest of all adaptations was really initiated, we cannot expect to bring to the point of demonstration; at best we can only venture opinions of probability. Still, this discussion commands at present more widespread interest among botanists than any other in the sphere of plant morphology.

There was a time when the attempt was made to reduce all plants to one scheme as regards their life-cycle, a method which not only prevented elasticity of theory, but was responsible for some unfortunate comparisons. It was characteristic of the period when the text-book of Sachs reigned supreme; we find it there definitely laid down that 'the doctrine of alternation has the object of reducing to one scheme the main phases of the life of all plants which bear sexual organs.' But the controversy between Pringsheim and Celakovsky had, as one of its results, the recognition of various types of life-history, not of one scheme only. The tendency at present is towards the opposite extreme; the frequency of the parallel developments now recognised has led some to accept a comprehensive polyphyletic view as regards alternation, and, wherever difficulties of comparison arise, to take refuge in the plausible suggestion that the organisms compared represent altogether distinct lines of descent. But the view which should be confidently upheld is that even where this may actually be the case useful comparisons may yet be made; and that the method of progress within one phylum may illustrate the probable mode of progress in another. The green Algæ may thus throw light upon the probable origin of the sporogonium in the Bryophytes, though they may in no sense be in the line of their descent; the Bryophytes may suggest valuable ideas for the comparative study of the Pteridophytes, though they may not represent their actual ancestry.

It is the alternation as seen in these green plants that I propose to discuss. Writers have distinguished various types of alternation, including under the term divers modes of 'alternation of shoots;' and it should be remembered that this was the original sense of the word alternation as applied by Steenstrup. But gradually the issue in the case of green plants has been simplified, and the question now centres round that alternation of phases which some of us describe as 'antithetic,' while others believe the phases to be really 'homologous' as regards their origin.

Briefly put, the question is, How was the first start made? Has the neutral generation or sporophyte been the result of change of any other part of the sexual generation than the zygote itself? If so, the alternation is of *homologous* generations; if not, then the alternation is what is styled *antithetic*. The whole discussion is like a purely historical inquiry, but with the minimum of documentary evidence; for on this point the fossils give scanty help. In the absence of more direct evidence we are thrown back on other arguments, such as those based on comparison of normal specimens, and secondly upon the study of abnormalities. I shall not attempt to treat the matter exhaustively; it will, however, be necessary for me to deal with certain points in the discussion which were raised in the able address of Professor Scott at Liverpool. He there restated Pringsheim's view of homologous alternation as against the antithetic. I propose now to consider three matters which I think are most material to the discussion—viz. (1) the bearing of the Algæ and certain Fungi on the question; (2) the comparison from the Bryophyta; and (3) the argument from abnormalities.

I. *Algæ and Fungi.*

At first sight those Algæ and Phycomycetous Fungi which show a subdivision of the zygote appear to offer the key to the enigma of the first start of antithetic alternation, and such rudimentary fruit-bodies as those of *Œdogonium* and *Coleochæte* are frequently quoted as prototypes of sporogonia. My own position has been that they may be 'accepted as suggestive of similar progress in the course of evolution of Vascular Plants.' On the assumption that the zygote is equivalent in all cases—and this is itself a pure assumption—the fruit-body of such Algæ or Fungi would be comparable to the sporophyte in higher forms; but it must be clearly remembered that it is not even then proved to be *homogenetic.* Dr. Scott has based a strong line of criticism of antithetic views upon these cases. He remarks: 'The sudden appearance of something completely new in the life-history, as required by the antithetic theory, has, to my mind, a certain improbability. *Ex nihilo nihil fit.* We are not accustomed in natural history to see brand new structures appearing, like morphological Melchisedeks, without father or mother. Nature is conservative, and when a new organ is to be formed it is, as every one knows, almost always fashioned out of some pre-existing organ. Hence I feel a certain difficulty in accepting the doctrine of the appearance of an intercalated sporophyte by a kind of special creation.'

In answer to this, I state that to me the zygote, from which our hypothesis starts, is not 'nothing;' it is a cell with all the powers and possibilities of a complete cell. Vöchting, in his 'Organbildung,' has fairly concluded that 'a living vegetative cell which is capable of growth has not a specific and unalterable function.' I have myself demonstrated that cells typically sporogenous may develop as vegetative tissue, and conversely that tissues normally vegetative may on occasions become sporogenous. We may, therefore, say generally, as regards the sporophyte, that 'a living cell which is capable of growth has not a specific and unalterable function.' This I conceive to have been the condition of the zygote, and of its early products.

I think that the words 'intercalation' or 'interpolation,' as used by writers on antithetic alternation, have been quite misunderstood. I have contemplated no sudden development—indeed, on the first page of my 'Studies' I have spoken of the sporophyte as 'gradually' interpolated. Nor is the suggested development something 'completely new,' for I specially speak of elaboration of the zygote. This is the parent of these 'morphological Melchisedeks;' and unless segmentation be held to be synonymous with 'special creation,' I confess I do not see where the initial difficulty arises. I agree that Nature is conservative; what we contemplate is the fashioning of the sporophyte by a process of which the first step is segmentation, out of a pre-existing organ—the zygote. Such simple segmentation is seen in the case of certain Algæ and Fungi, and these may be taken as suggesting how the sporophyte of the Archegoniatæ may have come to be initiated. But I am not aware of having ever suggested that these segmented zygotes of Algæ are the homogenetic prototypes of the more elaborate sporophytes.

Dr. Scott further states that 'the reproductive cells produced by the ordinary plant of an *Œdogonium* are identical in development, structure, behaviour, and germination with those produced by the oospore.' Professor Marshall Ward, also speaking of *Œdogonium*, remarks 'the attempt to get over this by terming asexual spores borne by the gametophyte *gonidia,* and reserving the term *spore* for bodies indistinguishable from these gonidia by any morphological or physiological character whatsoever, beyond their origin from a so-called sporophyte, carries its own refutation.' Now, as a matter of fact, Pringsheim's description and figures of *Œdogonium* give scanty details; in most of the germinating zygotes the nuclei themselves are not clearly shown; much less the details of behaviour of those nuclei on germination. Klebahn has described the fusion of the sexual nuclei in *Œdogonium*, but I am not aware that he, or anyone else, has yet made detailed observations on the nuclear condition of the zoospores, or the changes which take place in the germinating egg. Till this is done I submit that it is premature and undesirable to make such assertions as those of Dr. Scott and Professor Ward. We now know that important nuclear changes do take place on the germination of the zygotes of certain Algæ and Fungi. These changes are connected with a division of the nuclei into four, which is the number of the zoospores usually produced on germination in *Œdogonium*; the details may differ, but in the zygotes of *Closterium* and *Cosmarium*, and in the formation of the auxospores of *Rhopalodia*, Klebahn has demonstrated this division into four; also Chmielewsky has described a similar production of four nuclei in the germinating zygotes of *Spirogyra*. When it is further stated that in some of these cases there is good reason to think that a reduction of chromosomes is connected with the division into four, just as a reduction is now known to accompany the tetrad division in Archegoniate and Phanerogamic plants, it is plain that such cases as that of *Œdogonium* ought not to be assumed to support an homologous view without any fresh observation of the facts.

With the whole question of alternation, the nuclear details and differences in number of the chromosomes on division are now intimately bound up. Though the observations are still few, so far as they go they are consistent with the generalisation first stated by Overton, and elaborated by Strasburger as regards the Archegoniate and Phanerogamic plants. It has now been seen in cases drawn from various groups that the cells of the gametophyte show a certain number (n) of chromosomes, while those of the sporophyte show on nuclear division double that number ($2n$) of chromosomes. Since Section K has had the advantage of a statement on this subject from Professor Strasburger himself at Oxford, and as Dr. Scott also discussed the matter at Liverpool, I need not enlarge. I shall only remind you that Strasburger took up the position that the number of chromosomes which appears in each sexual nucleus is that original number which the ancestors possessed in a pre-sexual period; while the reduction of the double number which results from sexual fusion is, in his opinion, to be regarded as an atavistic process. As far as investigation has yet gone, I see nothing to prevent the acceptance of this as a provisional theory.

It is now well known, however, from the observations of Farmer and of Strasburger, that the nuclear conditions of *Fucus* are peculiar; that the reduction only takes place on the formation of the sexual organs themselves, and that the *Fucus* plant, like a sporophyte in the Archegoniate series, has the double number of chromosomes. At first sight this might appear to be a fatal difficulty, and Dr. Scott, attributing to the adherents of the antithetic theory views from which I personally dissent, has landed them in a seeming *reductio ad absurdum*. He himself does 'not think we are as yet in a position to draw any morphological conclusions from these minute differences, interesting as they are.' But we need not accept either of these extreme positions, if only a certain elasticity of theory be maintained, which should come naturally to adherents of polyphyletic development. I think the difficulty will chiefly be felt by those who, like some of the earlier writers on alternation, attempt to reduce all plants which show sexuality to one stiff scheme; this has been found to fail in the case of alternation, and a healthy recognition of various types of alternation has been the consequence. So in the matter of chromosomes, and of the position which the event of reduction holds in the life-cycle; difficulties such as this in *Fucus* may be anticipated, if we assume that all plants will conform to one plan. But Strasburger has not considered it necessary to cast aside the nuclear details as a basis for morphological conclusions, because all plants investigated do not fall in with a preconceived scheme. On grounds of comparison of behaviour of the nuclei before and after conjugation in *Closterium, Cosmarium, Spirogyra,* in certain Diatoms, and finally in *Actinophrys,* he has arrived at the conclusion 'that a shifting (Verschiebung) of the time of division into four, together with reduction, is possible in the history of development of organisms.' It will doubtless be necessary later to put a precise meaning upon the word 'Verschiebung,' and to define how far in given cases it is to be understood as an actual shifting of the event within one line of descent, how far it merely expresses an initial difference maintained, or it may be, extended, in different lines. Meanwhile, those who accept Professor Strasburger's position will see that while in various evolutionary sequences the reduction may take place at different points in the cycle, still it may have settled down to a fixed and constant position in any one sequence; that I conceive to have been the case for the Archegoniate series. The validity of this conclusion does not seem to me to be affected by the diverse state of things seen in so far removed a sequence as that of the brown Algæ.

Here a brief reference must be made to the very beautiful results of Wager on the changes in the zygote of *Cystopus candidus,* which have been verified and extended by Berlese. Wager states that in this fungus the process of fertilisation does not differ in any essential particular from the process as it takes place in Angiosperms. On the division of the fusion-nucleus of the zygote the number of the chromosomes present before division appears to be considerably in excess of the number observed in the nuclei of the oogonium. 'By counting as carefully as possible 20 to 24 or even more appear to be present, and the impression is produced that the number is certainly much larger than that observed in the oogonium.' Divisions of the nucleus then follow to form 4, 8, 16, and finally 32, in which condition a period of rest ensues; and, finally, it appears that a division of each into four follows, to form the nuclei of four spores. Wager believes the reduction to take place at this last division, and Berlese has established a strong probability that such a reduction actually does take place. Plainly these observations are not final or conclusive, and, even if they were, the strict homogeny of this fruit-body with a rudimentary sporophyte of a green plant would not be proved. It must, however, rank at least as an important parallel case, illustrating how the reduction may be effected in a distinct line of descent.

We see, then, that in green Algæ such as *Œdogonium, Sphæroplea,* and *Coleochæte* certain divisions follow fertilisation, but we are not yet in possession of the nuclear details. I prefer, therefore, to suspend judgment as to the nature of those divisions; but in view of the peculiar behaviour already seen in other zygotes it may be distinctly anticipated that some form of reduction will be demonstrated at that stage. If that be shown then we shall be right in recognising in these small cell-bodies the rudimentary correlative of a sporophyte—the sort of beginning from which a neutral generation may have sprung in land-living plants. We cannot go farther than this as regards the green Algæ until we are in possession of the facts. There is no greater desideratum in morphology at the present moment than a detailed knowledge of the germination of zygotes such as that of *Œdogonium.*

Here I may remark that the admirable observations of Professor Klebs, whom the Section will welcome as a distinguished guest, do not appear to me to touch this question. His very varied and convincing experiments show in a number of Algæ and Fungi that, as regards the succession of vegetative and sexual modes of propagation, the experimenter has a very complete control. I do not find, however, any observations of his which touch the behaviour of germinating zygotes of green Algæ as regards details of segmentation. I do not mention this as in the least impairing the brilliancy of Professor Klebs's work, but because Professor Ward has brought Klebs's results to bear upon the discussion on antithetic alternation in a manner which I do not think that the facts will support.

II. *Bryophyta.*

Turning now to the Bryophytes, these plants stand at the moment in a somewhat discredited position. We have been warned by Dr. Scott that 'there is no reason to believe that the Bryophyta, as we know them, were the precursors of the Vascular Cryptogams at all,' and that 'there is no appreciable resemblance between the fruit of any of the Bryophyta and the plant of any Vascular Cryptogam,' and the suggestion has been thrown out afresh that they may really be 'degenerate descendants of higher forms.'

In view of statements such as these it may be well to examine the Bryophyta quite separately, without reference to Vascular Plants at all, and see what are their main bearings on theories of alternation. And if the Bryophytes were the only Archegoniate Plants in the world, I think the case for their origin by a progressive antithetic alternation would be an uncommonly strong one; the points which are especially noteworthy are: (1) The readiness with which they may be arranged in natural sequences which illustrate increasing vegetative complexity of the sporophyte as a consequence of progressive sterilisation; (2) the nuclear details, which are as yet known, however, in only few cases; (3) the constancy of the two alternating phases, the relations of which are very seldom disturbed by apospory, and never, to my knowledge, by apogamy.

The first of these matters has been dealt with at length in my 'Studies.' It is, of course, possible for any one to read such sequences as are there mentioned in reverse order, and to uphold a theory of simplification; but this must be shown to be in accordance with probability. Now it appears to me that the general probability in the case of the Bryophytes is against simplification, for the larger the number of spores which can be matured the greater the probability of survival; even in cases where, as in *Buxbaumia* and *Diphyscium*, there is an exiguous, and probably reduced Moss-plant, the sporogonium is not of a reduced type, but, on the contrary, unusually large. It seems to my mind much more probable that the Bryophytes as a whole illustrate a course of progressive complexity. A comparison of anatomical details frequently suggests a progressive sterilisation, a process which we see demonstrated both in Pteridophytes and Phanerogams, where actual conversion of potentially sporogenous tissue into temporary or permanent vegetative tissue does occur. When it is added that the nuclear evidence, scanty though it still is, shows the sporophyte with a double number of chromosomes, and the reduction taking place on the tetrad division of the spores, the comparison with the segmented zygotes of Algæ and Fungi above mentioned seems inevitable. The position of those who hold views of antithetic alternation will, therefore, be that the simple sporogonium was produced as a post-sexual growth. The starting-point was probably some such multicellular body as we see nowadays in certain Algæ and Fungi resulting from division of the zygote, but not necessarily homogenetic with any such body that we know now living. The land-habit imposed a restriction on fertilisation, and an alternative method of increase in numbers was an advantage. The multicellular body resulting from division of the zygote provided the means for this; the cells developed separately as dry, dusty spores. As the number of divisions increased, the powers of the plant to nourish, protect, and disseminate the spores became the measure of the number produced. Hence followed the elaboration of the nourishing and disseminating mechanism, which has involved a diverting of some cells from their first office of spore-production, the start being, perhaps, made in a manner similar to the formation of the peridium in the Uredineæ. To my mind—taking the Bryophyta alone—there is an inherent probability in all this which far counterbalances any of the obstacles which have been raised against it.

The greatest obstacle is the fact of apospory in Mosses. This departure from the usual alternation will be more generally discussed in relation to the Ferns, where it is more frequent. Besides its being artificially induced in Mosses by special treatment, it appears also to have been noted by Ugo Brizi in Nature, in the case of atrophied capsules of *Funaria*, which had buried themselves in the soil. The essential point is the production of the sexual generation by direct vegetative growth from the neutral. This would appear to involve a reduction of chromosomes, but Pringsheim's drawings show nothing analogous to the usual process of tetrad division to form the spores; the reduction, if it occurs, must be effected in some other way.

A theoretical suggestion on this point will be made later. Meanwhile let us estimate its probable importance as regards the Bryophyta. It cannot fail to strike the observer how uniform is the alternation in these plants; there are, I believe, no recorded cases of deviation from the normal alternation in Liverworts. I know of only a single case of apospory among Mosses taken in the open, and then in atrophied capsules; apospory, when induced, follows such extreme treatment as chopping the sporogonium into pieces. And it is not as if the Mosses and Liverworts had escaped detailed observation; hardly any group of plants has been more carefully examined by competent observers. Deviations from strict alternation then are rare, and appear under physiological stress. This great group, which includes the simplest sporophytes among Archegoniate plants, is also singularly constant in its alternation. I think this is to be connected with the permanently dependent condition of the sporophyte; its equable physiological condition, nursed and protected by the Moss plant, finds its morphological expression in its comparative uniformity. Conversely, the independent position of the sporophyte in Ferns, and its exposure to varied conditions, may have elicited more freely in them unusual developments.

III. *Abnormalities.*

And now I may pass to my third point, and discuss more generally the argument from abnormalities. I have no wish to prejudge the question by the use of this term as applied to apogamy and apospory, or in any way to detract from their morphological importance—I merely intend to express that they are departures from that order of events which is the most frequent in Archegoniate plants at large, and I particularly wish to point out that while such irregular developments are now shown to be frequent in Ferns, they are exceedingly rare in Bryophytes, and are not, I believe, hitherto recorded for Lycopodineæ or Equisetineæ.

While direct vegetative transitions from one generation to the other may appear as a *primâ facie* support of an homologous origin of the two generations, I must protest against their being used, as they have been, as evidence against an antithetic view. It has been said that the facility with which these transitions from one generation to another in Ferns take place 'shows that there is no such hard and fast distinction between the generations as the antithetic theory would appear to demand.' Why should it demand a hard and fast distinction? For my own part, I had already described apogamy and apospory as occurring in the same individual before I wrote on alternation. The presumption seems to be that a distinct course of evolution must have imposed 'hard and fast' limits upon the potentialities of the parts evolved. But we ought to remember how the root, whether in Phanerogams or Ferns, has doubtless had a long course of evolution as a member distinct from the shoot; and yet we see it bearing adventitious buds upon it, as in the Rosaceæ, Poplar or Elm; or even transformed at its apex into a shoot, as in *Platycerium* or *Anthurium*. Such cases as these, though not exact parallels, should suffice to show that hard and fast lines are not to be anticipated as a consequence of a distinct course of evolution.

There is another kindred, though almost converse, proposition which has been advanced by Pringsheim. He made his experiments on Moss fruits, 'in the hope that he would succeed in producing protonema from the subdivided seta of the Mosses, and thus prove the morphological agreement of seta and Moss-stem.' The point here appears to be that parts which are capable of producing similar growths are in 'morphological agreement.' I cannot assent to this proposition. In the case of the roots above quoted, the production of buds upon them, or the conversion of their apices into shoots, does not prove their 'morphological agreement' with shoots upon which such developments are common.

By those who use such arguments it is to be borne in mind that the two generations, however distinct in their evolution, are still merely stages in the life-history of one and the same organism. The hereditary qualities of the race as a whole must be transmitted through the successive generations. It may be a question how far, and under what conditions, its various potentialities come into evidence, as, for instance, in the formation of an apogamous sporophyte, or of an aposporous protonema: but that some such potentialities are there is in no way inconsistent with the antithetic theory.

I have above pointed out how morphology has recently passed to an experimental stage, and I am glad to say that by means of the cultures of Dr. Lang and others we are beginning to gain an insight into the circumstances which lead to these phenomena. In certain Ferns direct apogamy occurs; that is, 'the immediate production of vegetative buds by prothalli which are usually incapable of being fertilised;' the origin of this is still obscure. But apogamy may also be induced in various other species. Dr. Lang states that 'the causes which appeared to induce apogamy in these prothalli were, the prevention of contact with fluid water, which rendered fertilisation impossible, and the exposure to direct sunlight. Possibly the temperature had some effect.' It is further to be noted that in every case of induced apogamy 'normal embryos were produced when conditions permitted fertilisation.' Now the conditions of prevention of fertilisation, exposure to light, and possibly also a high temperature, all lead to a plethoric state, which we may thus recognise as a precursor of induced apogamy, possibly also of apogamy at large.

On the other hand, the circumstances which precede or accompany apospory are commonly those of deficient nutrition. In the case of Ugo Brizi's *Funaria,* it is mentioned that the capsules were atrophied and buried in the soil, where they could not obtain nourishment by their own assimilation. In the induced apospory of Stahl and Pringsheim the growths appear upon parts of the chopped-up seta, isolated from their usual sources of supply. Among Ferns, the conditions of nutrition which precede apospory have not been noted in all cases; but the following facts are interesting. *Athyrium Filix-foemina* var. *clarissima* is a pale chlorotic Fern with exiguous leafage, while the more or less complete arrest of the sporangia is a concomitant of apospory. In *Polystichum Angulare* var. *pulcherrimum* there is no obvious disturbance of the vegetative organs, but I have specially noted the sporal arrest, which, in the specimens examined by me, appeared to be complete. This is, then, a concomitant of apospory, though it may be uncertain how far there is a causal connection. In the case of apospory in *Pteris aquilina,* reported by Farlow, there is an irregular diminution of leaf-area in the pinnules which show apospory; this is accompanied by various stages of abortion of the sporangia, though some fully-matured spores were found. Here, as also in *Polystichum angulare,* the tips are specially affected. Farlow remarks, 'the sporangia became more and more irregular the nearer they were to the tip.' In the case of *Scolopendrium vulgare,* the plants which showed apospory at so peculiarly early a stage had been raised by Mr. Lowe from prothalli which had been repeatedly divided, a process calculated to affect the physiological condition. The aposporous plants of *Trichomanes alatum, pyxidiferum,* and *Kaulfussii,* were all cultivated under artificial conditions, and are characteristically shade-loving plants, a habit which must affect their nutrition. Perhaps the most interesting case, however, is that described by Atkinson in *Onoclea.* In plants from which, by removal of the foliage leaves, the sporophylls had been induced to change their character and develop as foliage leaves, the sori were arrested. 'When the leaf has lost so much of its reproductive function that the sporangia are becoming rare or rudimentary in the sorus, apospory frequently occurs, and the placenta develops among the rudimentary sporangia prothalloid growths.' Here is, again, a case of deficient nutrition; the assimilating leaves, after formation, but before they could have carried their functions far, were removed. The plant makes an effort to supply their place at the expense of spore-production; arrest of sori and sporangia is the result, accompanied by cases of the direct vegetative transition to the prothallus. From these examples we see that deficient, or, at least, disturbed nutrition is frequently, perhaps always, a concomitant of apospory. Thus there is some countenance for the view that apospory and apogamy follow on converse conditions of nutrition.

We may next inquire how these converse conditions may lead to the changes in question; and especially the state of the nuclei ought to be considered. Owing to practical difficulties of observation the behaviour of the nuclei in apogamy and apospory has not been directly followed. But if the nuclear difference between the two generations be as it is believed, nuclear changes will be closely connected with these vegetative transitions. What could appear more natural than that apogamy, which presumably involves a doubling of the chromosomes, should follow a condition of plethora, and that apospory, which presumably involves a halving of the chromosomes, should follow deficient nutrition?

One further fact in either case appears to me to be specially noteworthy, that the changes are not confined to a single cell. The directly apogamous bud of *Nephrodium Filix mas* may perhaps be referable to a single cell, but Dr. Lang shows by numerous examples that the transition from characteristic tissue of the gametophyte to that of the sporophyte may arise at various points, and involve considerable tracts of tissue. Similarly, I have shown in the case of apospory that the change may affect not one cell only, but cell-groups at various and distinct points on the same individual. It would seem that there is a widespread disposition of the tissues to undergo the change.

For my own part, I think the usual attitude on the chromosome question has been too absolute and arithmetical. Evidence is accumulating from various sources that the usual numbers are not strictly maintained; it is known that in vegetative cells there are often considerable differences of the number of chromosomes from those in the sexual cells of the same plant, while observers have noted the irregularities in the divisions of the pollen-mother-cells in such plants as *Hemerocallis* and *Tradescantia.* If there be any causal connection between the number of chromosomes and the morphological character of the sporophyte and gametophyte, irregularities such as these at least countenance the idea of nuclear instability being possible; it will be a question for special treatment and investigation how far nuclear instability is connected with disturbed nutrition. But into the mechanism of the presumable nuclear change, and the question whether it be sudden or gradual, we cannot enter with any more than a speculative interest, in the absence of direct observations. Whatever the nuclear details may be, I regard it as a matter of very great importance to recognise that special conditions of nutrition commonly accompany, if indeed they do not actually determine, those changes which we term apospory and apogamy. But the story of the past is not simply a matter of conditions of nutrition, as we see them now influencing Archegoniate plants in their present highly specialised state. The real question is a purely historical one, How *did* the present state of things come about?

The following considerations influence me in forming an opinion as to the real place of apospory and apogamy in the history of the alternating generations:—

I. The Bryophytes show remarkable uniformity of alternation: irregularities are few; apogamy is not recorded; apospory appears rarely, as a physiological refuge for the destitute plant. This uniformity goes along with the protected and dependent condition of the sporophyte. All Pteridophytes have their embryos protected while young, and this seems to have been their primitive condition. The true lesson of the Bryophyta, which include the simplest living Archegoniates, seems thus to be that uniformity of alternation goes with a simple structure, and a protected or dependent condition of the sporophyte; and this we have reason to believe was the condition of the simpler Archegoniate fruits.

II. The distribution of apogamy and apospory among Archegoniates at large is very irregular; the Leptosporangiate Ferns are the head-quarters; but they are a peculiarly specialised phylum, with free sporophyte, exposed when mature, though protected while young. They are adapted to special conditions and show a greater plasticity of development than any other Pteridophytes. The Ferns are subject to other abnormalities than apospory and apogamy. The root may develop directly into a shoot, or the apex of the leaf into a bud. I think it has been too readily held that the Ferns occupy a special place as a key to the morphological problem. We should bear in mind how really isolated they are; they are essentially an extreme, even an extravagant type; they show the largest sporophylls in the whole vegetable kingdom, with the largest numerical output of spores from each. Many are specialised in accordance with extreme conditions of shade and moisture. These considerations should temper our view of them, not only as material for normal comparison, but also as exponents of abnormality.

III. The fact that in cases of induced apogamy in Ferns archegonia are first produced clearly shows that in these cases the first intention of the plant is towards a normal production of embryos, while apogamy takes its place as a substitutionary growth. It may remain an open question how far direct apogamy will bear a similar interpretation.

IV. The character of the aposporous and apogamous growths is very anomalous; their position is not definite; aposporous growths may arise from the sorus and sporangia, or from the most varied points on the margin or surface of the leaf. With regard to apogamy in Ferns, it appears, as the result of a large number of observations, that though there is an average normal of position, still any one part of the sporophyte—stem, leaf, ramentum, root, sporangium, or even tracheid—may arise, independently of others, from the prothallus. Single sporangia, or groups of them, may appear without vegetative organs of the sporophyte; leaves without other parts; in one case, I believe, as many as ten roots have been seen without any other members of the sporophyte! The close similarity of the parts thus irregularly placed to those formed in regular sequence in the normal plant should be a warning of their abnormality. I cannot see in them any suggestion of a primitive state. Dr. Lang tells me that these exceptional developments form only a small proportion of the individuals in any one culture; still they are there, and those who hold that apogamous developments are a suitable basis for morphological argument must not pick and choose those cases which suit their views, but must take even the most extravagant into careful estimation. My own view is that these anomalous growths are not a safe guide to past history. But looked upon as the result of a recently acquired transition from one generation already established to the other, following nuclear changes, in the one case of reduction after insufficient nutrition, in the other of doubling of the chromosomes following on plethora, apospory and apogamy are at least intelligible. We shall understand how the transition may take place at one point or at many, while the irregularity of the parts produced offers no morphological difficulty; it is rather what might have been anticipated if the transition were a ready consequence of the conditions we have noted.

Lastly, a word on Dr. Scott's utilitarian argument. He remarks: 'A mode of growth which affords a perfectly efficient means of abundant propagation cannot, I think, be dismissed as merely teratological.' We must be clear that utility is no certain evidence of antiquity. As refuges for the physiologically destitute, apogamy and apospory may play an important part *now*, and in so far are not to be dismissed as mere freaks of Nature. But in my view they would rank, as regards utility pure and simple, with the formation of adventitious buds on the root-system of a Poplar that has been felled; or with the bulbils which replace the flowers in so many mountain species; neither these, nor, I think, aposporous or apogamous growths, throw any direct light upon the story of descent.

To sum up, then, not only do I find that the facts in our possession, including the wildest anomalies, are consistent with an antithetic theory, but a comparison of normal forms seems to me to support the opinion that the sporophyte has appeared as the result of gradual elaboration from the zygote, a fresh phase having been thus gradually intercalated in the course of evolution. This idea, first clearly stated by Celakovsky in 1868, was developed by him in subsequent writings. I endeavoured to place it on a footing of adaptation to external conditions in 1890; and in 1897 we find Strasburger restating the position in terms almost identical with my own, but upon a basis of nuclear detail which had not been dreamed of when the view was first propounded. Dr. Scott has enthusiastically appreciated the double verification of the forecasts of Professor Pringsheim; I think that the way in which the antithetic theory is found to work in with the nuclear details recently discovered appeals quite as strongly to my mind.

In the course of this discussion I have not been anxious to point out such difficulties as beset the homologous view; all I have attempted here has been to set aside some of the difficulties which have been suggested in opposition to an antithetic view, and to show that the latter theory will adequately cover the facts.

Returning now to our general inquiry on homology, we see that on the antithetic view the two generations are not *homogenetic*; but they may be in a high degree *homoplastic*, and this homoplasy may be impressed upon the two generations, even in the same species, as in some Lycopods. I have never felt the cogency of the fact that the gametophyte of *L. cernuum* is somewhat similar in outline to the young sporophyte. Both generations are exposed to similar circumstances, and may be reasonably expected to have reacted alike. Moreover, the similarity of form of the 'leaves' of prothallus and plant is but slight, and is not maintained in allied species. Their arrangement is variable. Between them also lies the essential structural difference, so widespread among Archegoniate plants, that in the sporophyte stomata and intercellular spaces are present, in the gametophyte they are absent. These are just such differences as point to homoplastic development. More commonly, however, the homoplastic development is only seen in distinct organisms, and in this sense we shall rank the leaf of the Moss as the homoplast, but not the homogene, of the leaf of a Lycopod or of a Fern.

THEORY OF THE STROBILUS.

Some years ago I submitted to the Section a theory of the strobilus in Archegoniate plants. Comparisons were drawn between Pteridophytes and Bryophytes, and it was suggested that the origin of the strobilus of the former was 'from a body of the nature of a sporogonial head.' I specially pointed out at the time that my object was not a mere hunt after homologies, but to obtain some reasonable view of *the methods of advance* in Archegoniate plants. I wish to lay special stress upon this, for some appear to think that by denying an homology which I have not been at pains to maintain, they invalidate this search after the methods of advance. The Bryophytes as we now see them are our best guides in the search after these methods, even though they may not have been in the direct line of descent of Vascular Plants. As regards the comparison of the strobilus with a sporogonial head, I wish to make it clear that a *Moss* sporogonium is not specially indicated. The expression used has been 'the origin of the strobilus from a body of the nature of a sporogonial head'—that is simply a part of the sporophyte which bears spores internally as distinct from a lower vegetative region. We see in more than one sequence of Bryophytes how in a sporogonial head, as thus defined, the spore-production becomes restricted in extent, and relegated towards a superficial position by the formation of a central sterile mass. I am ready to join Dr. Scott in his confession of inability to find anything like an intermediate form between the spore-bearing plant of the Pteridophyta and the spore-bearing fruit of the Bryophyta, and to agree that at the best there is nothing more than a remote parallelism not suggestive of affinity; but none the less I think we should continue to search among the Bryophyta for suggestions as to the *methods* of advance, and to have confidence in transferring these ideas across the gulf, for I believe this to be both a reasonable and a promising method of study.

DORSIVENTRALITY.

Interesting questions arise in connection with dorsiventral structure. In the Equisetineæ, and almost all Lycopodineæ, the strobilus is of the radiate type, therein corresponding to the radial structure of typical sporogonia. While certain Ferns are of the radiate type, others are conspicuously dorsiventral, even from their earliest embryonic state. Dorsiventral structure also appears in the vegetative region, and sometimes, though rarely, in the strobilus of *Selaginella.* Professor Goebel, in a chapter of his 'Organographie,' the publication of which may be recognised as the leading event in the morphological studies of the year, discusses the origin of the dorsiventral state in a number of examples, and his results have a most interesting bearing on our theory of the strobilus.

He shows in the case of *Vaccinium Myrtillus* how the first shoot of the seedling is orthotropic and radial; the lateral shoots, formed after the apical growth of this is arrested, are also orthotropic, but the lateral shoots of higher order become plagiotropic with leaves in two lateral rows. He points out the intermediate steps from one condition to the other, and how finally the growing point itself is influenced by the external agency (apparently light), which leads to a change of the leaf-arrangement. This seems to be the case in many other Phanerogamic plants.

A particularly interesting account is also given of similar changes in *Selaginella*. Some eight species are orthotropic, radial, and isophyllous. *S. sanguinolenta* shows a direct response to external conditions, being upright and isophyllous in bright and dry situations, plagiotropic and anisophyllous in damp and shady situations. The bulk of the genus are, however, either plagiotropic and anisophyllous throughout, or some may have an early orthotropic stage. But he concludes that even in 'habitually' anisophyllous *Selaginellas* we have to do with an adaptive character, induced probably by light.

We see then good evidence that in certain cases the dorsiventral shoot is a result of adaptation, and the radial probably the primitive. Was this always so? We need not discuss the case of the gametophyte, as the problem there is even more varied and difficult, and does not at the moment engage our attention. But the question whether in the sporophyte the radial was in all cases the primitive type is clearly related to our theory of the strobilus. The sporogonia of Bryophytes are, with few exceptions, orthotropic, and almost uniformly radial; exceptions such as *Diphyscium* and *Buxbaumia* have been shown to have an interesting relation to the incidence of light, and are readily recognised as derivative. The distinctively strobiloid Pteridophytes mostly maintain this radial structure; this may be so both in strobilus and vegetative organs, as in *Equisetum*, *Isoetes*, in most species of *Lycopodium*, and in some *Selaginellas*; or the vegetative region may be dorsiventral, and the strobilus return to the radial type, as in some species of *Lycopodium* and most *Selaginellas*; but in some *Selaginellas* even the strobilus may be dorsiventral.

In the Ferns the case is less obvious; the large size of the leaves, combined often with a dorsiventral structure of the shoot, makes a comparison with a radial strobilus less easy. Goebel has pointed out that in many dorsiventral Ferns the dorsiventrality is already defined in the *punctum vegetationis*, and does not depend upon a subsequent shifting of the parts. But it should be remembered how many Ferns are orthotropic and radial; that almost all the large genera include species with simple unbranched leaves. Further, the series of the Ophioglossaceæ, possibly a distinct phylum from the true Ferns, may be held to illustrate a progressive elaboration of the leaf, from smaller-leaved forms which are orthotropic and radial, to larger-leaved forms, which are sometimes orthotropic and radial (*Botrychium*), sometimes plagiotropic, and dorsiventral (*Helminthostachys*). It is not, I think, improbable that these, and also the true Ferns, are referable in origin to an orthotropic strobiloid type, with radial structure. This opinion was in substance suggested in 1894 at Oxford; these recent observations of Goebel on the derivative nature of dorsiventral shoots strengthen the position then taken up, while they supply us with fresh examples of homoplastic development.

CONCLUSION.

This discussion was entered on with a view to finding whither phylogeny as a basis of morphology would lead us. However unprepared we may be to pursue it with certainty into detail, or to apply a terminology to the sequences which we recognise, we must, I think, accept phylogeny as the natural basis for morphology. I do not think that any middle course between this and an artificial system is possible or reasonable. But here we launch ourselves upon a sea of uncertainties on which we must keep our course with care. Following it, we think we espy certain great movements in Nature. We may recognise what we believe to be a true evolutionary sequence, but who is to say whether it is a progressive or a retrograde sequence? It may even be one divergent from some middle point. Our best friend may read the sequence in opposite order to ourselves and arrive at a diametrically opposite conclusion. There is no finality to this judging of probabilities, a fact which should be always before the mind, especially in the warmer moments of discussion.

It is interesting to trace the parallel between the progress of classification of plants as a whole, and that of the classification of their parts. In each case the earlier systems were artificial. We may compare the Linnæan system of taxonomy with the Hofmeisterian organography: in both the rigid application of a preconceived method placed incongruous things in juxtaposition, in each case a widening of the basis of the classification has resulted in a redistribution on more natural lines. The present ideal of taxonomy is the same as that of the phylogenetic organography, viz. to group according to descent. The limitations are alike: systematists and morphologists both find their greatest difficulty in the incompleteness of the record, and the frequent isolation of the things to be classified.

But without following the obvious parallel further, we may now briefly review our position as regards organography, and the following categories are to be recognised, though they graduate almost imperceptibly into one another:—

Homogeny.—(*a*) *Repetition* of the individual part in successive generations, with the same number and position. This is exemplified by the cotyledons, the foot, and first root.

(*b*) *Essential correspondence* of parts varying in number and position, but corresponding in character and development, produced in a regular sequence; e.g. most cases of continued embryology.

(*c*) *Transferred position* of parts, similar in origin and structure to those produced in regular sequence; e.g. roots, adventitious buds, sori of *Aspidium anomalum*, aposporous and apogamous growths, many monstrosities; these we may believe to result from a transfer of inherited developmental capability.

Homoplasy.—This may be recognised with varying degrees of probability; starting from cases where the question of community of descent is open (as with nearer circles of affinity), and proceeding to those in which distinct evolution is virtually certain. It remains for future investigation to clear up doubtful points. Meanwhile, taking the case of leaves for the purpose of illustration, we may contemplate the following possibilities:

(*a*) A possible origin of two homoplastic series of leaves in the same plant, and the same generation (*Phylloglossum*).

(*b*) Two homoplastic series in the same plant, but in different generations (*Lycopodium cernuum*).

(*c*) A possible distinct origin of homoplastic leaves in distinct phyla, but in the same generation (sporophyte of Ferns, Lycopods, Equiseta).

(*d*) A distinct origin of homoplastic leaves in distinct phyla, and distinct generations (e.g. leaves of Bryophyta and of Pteridophyta).

Now *Homology* has been used in an extended sense as including many, or even all, of these categories. It seems plain to me that this collective use of the term homology carries no distinct evolutionary idea with it; it indicates little more than a vague similarity; the word will have to be either more strictly defined or dropped. The old categories of parts based upon the place and mode of their origin are apt to be split up if the system be checked by views as to descent. Comparison, aided by experiment, supersedes all other methods, and the results which follow raise the question of terminology of parts which have arisen by parallel development.

In parts which are of secondary importance, such as stipules, pinnæ, the indusium, hairs, glands, the inconstancy of their occurrence points to independent origin by parallel development in a high degree; in parts of greater importance, such as leaves, a parallel development may also be recognised, though in a less high degree; in the case of sporangia their acceptance as a category *sui generis* dispelled the old view of their various origin from vegetative parts; but we must remember that this does not by any means exclude a parallel development also in them, by enlargement and septation from some simpler spore-producing body, though this is not yet a matter of demonstration. Finally, the sexual organs are probably homogenetic in all Archegoniate plants, but we have no proof that sexuality arose once for all in the lower plants; the probability is rather the contrary. Thus we may contemplate as very general a polyphyletic origin of similar parts by evolution along distinct lines, but resulting, it may be, in forms essentially similar.

There are two extreme courses open to those who wish to convey clearly to others such matters as these; the one is to use a separate term for each category of parts, which can be followed as maintaining its individual or essential identity throughout a recognised line of descent—in fact, to make a polynomic terminology of members run parallel with a polyphyletic development. The other course is to make it clear always in the use of terms applied to parts, that they do not convey any evolutionary meaning, and to use them only in a descriptive sense. Perhaps the former is the ideal method, and it may be a desirable thing, as polyphyletic origins of parts become more established, that the terminology should be brought to reflect at least the more important conclusions arrived at. How this may be done we leave for the future to decide, though I have indicated a first step in the case of the leaves of Mosses and Ferns.

But, for the present, the whole matter is still so tentative that it is well to be content with something which falls short of the ideal, and to maintain the usual terms, such as stem, leaf, root, hair, sporangium, &c., as simply descriptive of parts which correspond as regards general features of origin, position, and nature; but with no reference either, on the one hand, to conformity to any ideal plan, or, on the other, to any community by descent—in fact, we shall preserve the original pre-Darwinian sense of these words, which was purely descriptive, and avoid any attempt to read into them any accessory meaning.

A special interest attends those cases of transfer of inherited developmental capability where a part appears with its normal characters, but in a position which is not usual, such as the transfer of the sori of *Aspidium anomalum*; comparable with these transfers on the one hand are those apogamous growths where roots, leaves, ramenta, sporangia may arise independently out of the usual succession. These may be compared, on the other hand, with those interpolations of extra parts, such as the accessory stipules in the stellate Rubiaceæ, the extra stamens in Rosaceæ, &c. We are unable as yet to say what it is which determines the position and mode of origin of parts; I do not myself think that Sachs's hypothesis of 'Stoff und Form,' involving ideas of material differences which have not been demonstrated, will advance the question so much as a careful following of the details in the origin of the parts, say in some of these apogamous growths. Here we see the plant body in a sense analysed before us; any one part may be produced separately from any other. An elucidation of how any one of these is initiated and determined should lead to a knowledge of the influences which act also in the normal sequence, and determine the origin of parts in the plant body at large.

I have attempted to touch upon some of those questions in the Morphology of Plants which specially interest us at present, and I dare say in doing so have revealed to you some of the special weaknesses of this branch of the science. The want of finality in this unravelling of history without documents, the ample latitude for difference of opinion, according to the relative weight attached by one or another to the same facts: these are difficulties inherent in the very nature of our study, while to many minds they increase rather than diminish its attractions. Nevertheless the progress of morphology in late decades has plainly been towards a truer appreciation of how divers forms have originated, and so towards a better recognition of affinities. Seeing that this is clearly the main trend, we may take heart as to the advancement of morphological knowledge. We shall not allow ourselves to be deterred by reason of the want of finality or the deficiency of evidence, however strongly we may feel the weight of these difficulties. We shall rather try to make the best of such evidence as we possess, with the full confidence that, however insoluble the problem of descent may really be, inquiry along scientific lines will at least lead us nearer to the goal.

The following Report and Papers were read:—

1. *Report on Fertilisation in* Phæophyceæ.—See Reports, p. 729.

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2. *On the Form of the Protoplasmic Body in certain Florideæ.*
By REGINALD W. PHILLIPS, *M.A.*, Bangor.

In *Ceramium rubrum* and other species a strong strand of protoplasm runs along the axial cells from pit to pit. In this strand the nucleus is occasionally suspended; more often it lies over the pit at the base of the strand.

In *Dasya coccinea,* the branches of limited growth run out into pointed uncorticated filaments, the cells of which are large. Across the vacuole of these cells running from pit to pit occurs a thread of protoplasm much more delicate than the corresponding structure in *Ceramium.*

In *Callithamnion byssoides,* threads of protoplasm radiate from a cushion lying over the pit and end blindly on the vacuole. These threads are in incessant movement, swinging over, bending on themselves, and extending or retracting. All these phenomena point to the great physiological importance of the pit-communication between cell and cell.

3. *On Reproduction in* Dictyota dichotoma. *By* J. LLOYD WILLIAMS, *Assistant Lecturer and Demonstrator in Botany, North Wales University College, Bangor.*

1. *Dictyota* is an annual. In this country it germinates during the summer, remains small during the winter, grows very rapidly in June, and begins to form its reproductive cells in July.

2. The tetraspores are produced throughout the season, and all stages may be found together on the same plant. The sexual cells, however, show a remarkable periodicity. The formation, maturation and liberation of each crop occupies a fortnight, the interval between two spring tides. The sori are formed during neap-tides, and the cells are liberated during, or immediately after the highest spring-tides.

3. When liberated the oospheres are not invested with walls. In this condition they strongly attract the antherozoids, become fertilized, and at once start germinating. The plantlets are similar to those figured by Thuret as resulting from the germination of the tetraspores.

4. If not fertilized the eggs lose the power of attracting antherozoids, they form walls, and, as already described by Thuret and Bornet, they germinate parthenogenetically. After one, or a few divisions, sometimes accompanied by formation of rhizoid rudiment, the process stops and the plantlets die.

5. Towards the close of the season some sori fail to mature within the usual period, and the crops become less regular; the same effect is brought about during very cloudy and cold summers.

6. The same conditions bring about sterilization of certain of the sexual cells. Thus, patches of cells within the antheridiæ sori fail to divide. Cells at the margins of female sori remain barren, so that the usually borderless sori acquire partial, or even complete borders.

7. There are strong reasons for concluding that the factor which determines the maturation and liberation of the sexual cells, and the fertilization of the oospheres, is the amount of the illumination to which the plants are subjected.

8. The cytology of the reproductive cells will be described as far as it has been made out.

4. *On the Origin of Railway-bank Vegetation. By* S. T. DUNN.

The surface of embankments and cuttings on English railways becomes covered, after some years, with the same vegetation as can be found on any grassy slope in their neighbourhood. Mixed with this, however, may usually be seen a certain number of species of distant origin. The bare earth of the new embankment gets sown with wind-blown seeds, both cuttings and embankments being likely to arrest their flight and to afford a footing to even those which cannot compete successfully with the native species. Seeds, also, which were in the earth used for making the embankments give rise to garden, corn-field, and meadow plants characteristic of the ground broken in making the cuttings.

After traffic has been established on the line, a new source of weeds is opened. By the continual packing, unpacking, and carriage of merchandise, station sidings become the homes of certain weeds which are found in such places and transported by the same means over most of the temperate world. Their seeds spread along the line from these centres, drawn by the natural draught along the slopes in some cases, carried on the trains in others.

From the beginning there has also been a third agency at work, the natural encroachment of the surrounding vegetation.

On the average railway bank we find a large proportion of native species, a few visitors either established or constantly reinforced by traffic, and lastly an occasional straggler resulting from the original composition of the bank.

FRIDAY, SEPTEMBER 9.

The following Papers were read:—

1. *A Method of obtaining Material for Illustrating Smut in Barley.*
By W. G. P. ELLIS, *M.A., Bot. Laboratory, Cambridge.*

By sowing soaked, skinned barley that had been plentifully covered with *Ustilago* spores a supply of smutted barley may be ensured, and in such material it is easy to trace out the spore formation.

Hand section of the ear when about $\frac{3}{8}$ inch long showed the mycelium at the growing points of the flower shoots, and in such sections the mycelium, at first intercellular, could readily be found becoming intracellular and of much greater diameter. Branches became very numerous, and in the hyphæ and branches spores were formed. Towards the central parts spore clusters were too dense for examination, but nearer the epidermis the branching and arrangement of the sporogenous hyphæ could more easily be made out; and the teasing of the lateral flowers of each notch of the rachis was often more successful than if the central—and *only* flower of the ordinary ear—were taken. Sections were mounted in water, and some in 1 per cent. KOH, and it is but fair to say that such treatment has failed to show any septation of the hypha as a preliminary to spore formation. Material for microtome sections was prepared as follows:—The leaves of a barley shoot were stripped down so as to expose the apparently highest node, and the part an inch or two above this was cut off; then by a series of successively lower horizontal cuts the youngest leaves were removed until in the space they enclosed the tips of the awns or ear were seen; then a cut was made through the node and the removed ear was placed in Flemming's or Rath's solution for fixing, the ear thus being a very few seconds only between plant and reagent.

If a smutted ear be removed and kept floating on water, its spores continue to develop, and in several cases they matured first in the awn. It was by no means uncommon, on teasing out young fruits from such an ear, to find that the spore had germinated.

I have not yet made similar observations for *Tilletia*, as my bunted wheat was less forward than my smutted barley, but I am satisfied that by this method of working, class material for illustrating Bunt and Smut may easily be obtained.

2. *On a new* Medullosa, *from the Lower Coal-Measures of Lancashire.*
By D. H. SCOTT, *M.A., Ph.D., F.R.S., Hon. Keeper of the Jodrell Laboratory, Royal Gardens, Kew.*

Our knowledge of the remarkable fossil stems referred to the genus *Medullosa* of Cotta has hitherto been based entirely on Continental specimens, chiefly derived from the Permian Formation. The author describes English specimens of *Medullosa* from the Lower Coal-measures at Hough Hill, in Lancashire, found by Mr. Lomax and Mr. Wild. The specimens are thus from an horizon considerably lower than those previously recorded. The stem is somewhat simpler in structure than that of other *Medullosæ*, and shows very clearly that its organisation is essentially that of a polystelic *Heterangium*. The *Myeloxylon* petioles are found in connection with the stem, thus affording new confirmation of the views of Schenk, Solms-Laubach, and others as to the relation between the two supposed genera.

The triarch adventitious roots belonging to the *Medullosa* stem are also described. The new species illustrates with great clearness the remarkable combination of Filicinean and Cycadaceous characters which the *Medullosæ* present.

3. *On the Alcohol-Producing Enzyme in Yeast.*
By Professor J. R. GREEN, *F.R.S.*

At the meeting of the Botanical Section at Toronto last year the author gave an account of some experiments which he had made during 1897 with a view to confirming the work of Dr. Buchner on this subject. These experiments only yielded a negative result. During the present year he has carried them further, giving attention particularly to the condition of the yeast at the time of the preparation of the extract. He finds that at the time of very active fermentation the enzyme can be procured as Buchner has stated. The author cultivated about 2 lbs. of a very pure yeast in an incubator, and, when the growth of the yeast was at its maximum, he rapidly dried and ground it as Buchner recommends. The expressed liquid immediately set up evolution of CO_2 in a solution of cane sugar, maintaining for several days a free pressure in a manometer affixed to the flask in which the operation was carried out. The liquid lost weight at the same time, and there was a coincident formation of alcohol. The gas was proved to be CO_2 by leading it into baryta-water. When in a separate experiment it was absorbed by potash the gain of weight by the latter corresponded to the loss of weight by the fermenting liquid.

The operation was conducted in the presence of excess of chloroform to secure the absence of bacteria and to check the development of yeast cells should a few of them have obtained admittance to the liquid.

The enzyme agrees in an important respect with other enzymes. It is carried down to a very considerable extent, if not completely, by the formation of an inert precipitate in the liquid.

4. *A Potato Disease.* *By* H. MARSHALL WARD, *D.Sc., F.R.S., Professor of Botany in the University of Cambridge.*

I have for some time past had occasion to recognise here and there, in various parts of England, a potato disease which is not due to *Phytophthora*, and which has often been ascribed to bacteria. During the past two years my attention has been especially directed to testing its bacterial origin, and I am convinced it is not due to bacteria, but to a true hyphomycetous fungus.

Without going so far as to say there is no bacterial disease of the potato, I wish to express the conviction that the alleged cases of such lately published are not convincing, and that a tendency exists to draw conclusions from imperfect evidence.

I shall show that the way into the tuber is prepared for bacteria by fungus hyphæ, and the open passages of destroyed vascular bundles afford them ample space. The disease I have studied has appeared in a more or less epidemic form at least twice in my experience: it was very common two years ago, and this year has been abundant in various parts of England. In a subsequent publication I shall show that it is common and wide-spread, and even known in some countries, though not adequately recognised.

Symptoms.—The shoots turn yellow and die prematurely during the summer, and before the tubers are anything like full. The disease *starts from below* and *not from the leaves.* The roots are few and poor, and soon rot away. The tubers are few, do not mature, and often rot in the ground. The leaves turn yellow and wither on the stems, with the symptoms of *premature wilting,* and often remain long hanging on the yellowing, glassy-looking, but still living stems.

In very mild cases these symptoms are not obvious, and supervene slowly, and the case may be complicated by the co-existence of *Phytophthora.* In very severe cases, on the other hand, especially in wet situations, the stems and roots may be all rotten by the end of July, and casual observation may ascribe the damage to *Phytophthora* entirely. In ordinary cases, again, it is easy to suppose the damage due to some insect attack, or to drought.

In advanced stages of the disease the stems either dry up to brown sticks, or putrefy on the wet ground; very often bacteria have gained access to the tissues at a comparatively early stage.

Microscopic Appearances.—Sections across the lower parts of the attacked stems show one, two, or more of the vascular bundles yellowish-brown—visible even without a lens—and the principal vessels of these contain branched, septate hyphæ. In several cases I have traced these hyphæ through every internode of the stem, into the petioles of the still hanging leaves, into the young lateral shoots, throughout the roots and subterranean rhizomes, and *up to and even just into the tubers.* In two cases I have done this in one and the same potato-plant, and so have no longer any hesitation in ascribing the disease to this fungus, the morphological features of which will be described in a subsequent paper. In advanced cases the brown vessels are stopped with a yellowish gum-like substance. Tyloses are common in the vessels of the root. Those tubers which are not attacked while still very young, but which have already begun to fill with starch, may offer considerable resistance to the invasion of the fungus; but eventually the vascular strands diverging from the point of attachment to the rhizome exhibit the telltale foxy-red or yellowish-brown colour, and in many cases the ripened tubers are to all appearance sound, except for *microscopic reddish spots just at the points of entry of these bundles.*

During the winter the stored potatoes, with the fungus thus just lurking in them at the morphological base (the so-called heel) of the tuber, may undergo little change to all appearance *if gathered and stored dry.*

But if wet, various kinds of rot may supervene, owing to the *subsequent invasion* of various micrococci, bacteria, fungi, &c. following the lines of weakness opened up by the fungus in question, and living as saprophytes on the stored reserves.

In some cases even apparently dry tubers may undergo a curious rot—dry-rot—owing to the ravages of a particular bacterium or mould, perhaps more than one, which finds sufficient moisture for its purposes.

The principal point is that the fungus I have especially studied leads the way for these purely saprophytic anaërobic and aërobic forms into the tuber: once in the mature tuber, its progress is necessarily slow until the reserves move in the spring.

During the past winter I gave to Miss Dawson, who is working at such subjects in my laboratory, some of the tubers saved from plants attacked with this disease, to investigate the various fungal forms lurking in the diseased tubers. Her investigations are not yet completed, but enough has been accomplished to convince us that after the fungus in question has opened up the way into the tuber, all sorts of bacteria and fungi can make their way down the destroyed vascular strands, and reappear in spring, when the tubers are replanted.

But this is not all. The evidence shows that the fungus in question, once in the tuber, leads a dormant life during the early part of the winter, but gradually invades the new sprouts as they slowly appear in the early spring, and that *the parasite is actually replanted* by the farmer or gardener, when restocking the ground, *in his new 'sets.'*

If we reflect that the tuber is really a bud, there is nothing especially strange in this phenomenon; the fungus enters the base of the bud in autumn, and takes some months to traverse its dormant tissues during the winter and spring. A spotted tuber may give rise to some healthy and some diseased sprouts, according to the tracks of the fungus.

A curious phenomenon was observed in some potato-plants very badly attacked by this disease this summer. In some of the badly diseased young shoots quantities of beautifully developed *cubical proteid crystals* (crystalloids) were observed in the parenchyma of the pith and cortex. It is due to Mr. W. G. P. Ellis to point out that he was the first to see these in some sections he was kindly cutting for me of this batch of specimens. On going further into the matter I find such crystalloids have been seen by Heinricher in the shoots of a diseased potato,[1] but he did not give any account of the disease itself.

I find these crystals are not uncommon in the still green bases of the petioles of the withered leaves hanging on the diseased shoots, though they do not always occur.

I ascribe their formation to the accumulation of proteids in the leaves, while still living and active, from which the passages of transference at the nodes of the stem have been cut off by the fungus; just as the eventual withering of the leaves is due to the blocking of their water-conduits when all the vessels are stopped up.

At the same time, the attempts I have made to induce the formation of these crystalloids artificially have failed so far.

Neither ringing, nor ringing combined with destruction of the pith with a hot skewer—to destroy the internal phloëm—has given satisfactory results as yet, though the leaves of healthy plants withstand this drastic procedure much better than might be supposed.

Here again I must reserve further particulars for the fuller paper.

In conclusion, it is evident that the efforts of the potato-grower must be directed to the selection of sound sets, and to the careful preparation of his ground. I hope to show later that it is a fatal procedure, even with sound sprouts, to allow the young shoots to lie in contact with raw manures, as it is *viâ* wounds and small rotting spots at and near the collar that new infections occur. The same arguments apply to wet soils and situations, and the disease is particularly apt to increase when wet and cold weather supervenes on the early growths.

5. Penicillium *as a Wood-destroying Fungus.*

By H. Marshall Ward, *D.Sc., F.R.S., Professor of Botany in the University of Cambridge.*

Spores from pure cultures of *penicillium* were sown on sterilised blocks of spruce-wood, cut in March, and were found to grow freely and develop large crops of spores on normal conidiophores. Sections of the infected wood showed that the hyphæ of the mould entered the starch-bearing cells of the medullary rays of the sap-wood and consumed the whole of the starch. The resin was untouched. In culture three months old the hyphæ were to be seen deep in the substance of the wood passing from tracheide to tracheide *viâ* the bordered pits. Control sections, not infected and kept side by side with the above, contained abundance of starch, and no trace of hyphæ could be detected in them.

The observation appears of interest in several connections. *Penicillium* is one of our commonest moulds, and undoubtedly plays a part in the reduction of plant *débris* to soil-constituents; how far it can itself initiate the destruction of true wood, or how far it merely follows on the ravages of other fungi, bacteria, &c., is unknown. There are strong grounds for believing that it destroys the oak of casks, &c., but since these are impregnated with food-materials this is not very surprising. Trabut[2] has shown that *penicillium* will grow in solutions containing 2–9·5 per cent. of $CuSO_4$, and other evidence exists showing how remarkably resistant this mould is, and how little organic matter it needs for life.

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[1] *Ber. d. deutsch. bot. Ges.* 1891.

[2] *Bull. de la Soc. Bot. de Fr.*, xlii., 1895, 1.

Dubois[1] showed that *penicillium*, or a closely-allied form, not only lives in strong solutions of copper, neutralised with ammonia, but will erode metallic copper and bronze if transplanted thereon.

Iönssen[2] found *penicillium* living in one-tenth normal sulphuric acid solution, and gives some interesting facts regarding the sulphur-containing oil-drops in its protoplasm, and other statements concerning oil in this fungus occur in the works of De Bary, Brefeld, Pfeffer, &c.

Gerard[3] gives proof that *penicillium* can liberate butyric acid from monobutyrine, and evidence that this is due to its power of forming a *lipase* or fat-splitting enzyme.

Lesage[4] gives striking instances of the resistance to external influences shown by the spores on germination. Not only will they germinate and live for some time in water, and under almost anærobic conditions, but he found them germinating in 26·5 per cent. solutions of common salt; 30 per cent. solutions were too much for them, however. He states also that the vapour of cedar-oil, iodoform, napthalin, camphor, and patchouli do not prevent germination; though that of clove-oil, ether, alcohol, chloroform, and acetic acid prevent it. The maximum for alcohol was somewhere between 4·2 and 6·2 per cent. In acetic acid they germinated in twenty-four days in solutions of 1 : 256, but failed to do so in solutions of 1 : 64, whereas in HCl they germinated in two days in 1 : 4 solutions.

As regards temperatures, it is well known how resistant the spores are; a striking instance of the hardships the mycelium can undergo is given by Woronin.[5] He found *penicillium* vegetating on the melting snow, where the temperature at night fell below 0° C.

Bourqueot[6] found Invertase, Maltase, Trehalase, Emulsin, Inulase, Diastase, and Trypsin in the allied *aspergillus*, and pointed out how suggestive this is in explaining the ubiquity of this mould. Probably *penicillium* is equally rich in capacity for enzyme-production.

Miyoshi[7] showed that *penicillium* can bore through cellulose membranes, and no doubt similar chemotactic phenomena are concerned in the piercing of wood-elements by the hyphæ.

It certainly looks as if *penicillium* may be a much more active organism in initiating and carrying on the destruction of wood than has hitherto been supposed, and that it is not merely a hanger-on or follower of more powerful wood-destroying fungi. It is also, doubtless, very independent of antiseptics.

SATURDAY, SEPTEMBER 10.

The following Papers were read:—

1. *On a Fine Specimen of the Halonial branch of a* Lepidodendron *allied to* L. fuliginosum (*Will.*). *By* D. H. Scott, *M.A., Ph.D., F.R.S.*

This specimen (of which a photograph is exhibited) was recently discovered by Mr. Lomax at the Hough Hill Colliery. It is of large size, with the structure perfectly preserved, and bears two series of Halonial tubercles. The main stem resembles that of *Lepidodendron fuliginosum*, though not absolutely identical. Each tubercle has its own vascular cylinder, surrounded by leaf-trace bundles, and evidently represents a branch, which probably constituted the peduncle of a strobilus.

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[1] *Comp. Rend.*, 1890, cxi., p. 655.
[2] *Bot. Centr.*, xxxvii., 1889, p. 201.
[3] *Bull. de la Soc. Mycol. de Fr.*, xiii., 1897, p. 182.
[4] *Ann. des Sc. Nat.*, Ser. 8, T. 1, 1895, p. 309.
[5] *Arb. d. St. Petersb. Naturf. Ver.*, B. xx., p. 31.
[6] *Bull. Soc. Mycol.*, 1893, p. 231.
[7] *Bot. Zeit.*, 1894, H. 1.

2. *On an English* Botryopteris. *By* D. H. SCOTT, *M.A.*, *Ph.D.*, *F.R.S.*

Specimens are described, showing that *Rachiopteris tridentata* (Will. in litt.) is the petiole of *Rachiopteris hirsuta* (Will.), a simple monostelic Fern-stem. It is further shown that the plant agrees closely in structure with the peculiar group of fossil Ferns described by M. Renault under the name of *Botryopteris*, and that it should be placed in that genus.

3. *On the Structure of* Zygopteris. *By* D. H. SCOTT, *M.A.*, *Ph.D.*, *F.R.S.*

Undescribed specimens, from the Williamson collection, of the Fern *Rachiopteris Grayii* (Will.), which is no doubt a *Zygopteris*, show the anatomical structure more perfectly than any previously investigated. The stem has a very complex organisation, though of the monostelic type; the leaves have a 2/5 phyllotaxis; the vascular strand of the axillary shoot is given off from the foliar bundle a short distance above its base.

4. *A Rare Fern*, Matonia pectinata (*R. Br.*) *By* A. C. SEWARD, *F.R.S.*

An account was given of the external character, internal structure, and geological history of *Matonia pectinata* (*R. Br.*). The material was received through the kindness of Mr. Shelford, of the Sarawak Museum, Borneo. The structure of the stem was described in detail and recognised as distinct from that of any known fern. The genera *Matonidium* and *Laccopteris* were briefly described, their fronds, sori, and distribution being compared with the external characters and geographical range of the recent species. Mr. Seward pointed out the advisability of placing the two living species of *Matonia* in a special group on account of their isolated position among existing ferns.

5. *The Prothallus of* Lycopodium clavatum (*L.*). *By* WILLIAM H. LANG, *M.B.*, *B.Sc.*, *Lecturer in Botany at Queen Margaret College, Glasgow University.*

A few prothalli of *Lycopodium clavatum* were found wholly imbedded in the peaty soil underlying a patch of moss; three of them bore young plants and a number of slightly older plants, the prothalli of which had disappeared, were found in the same spot. The prothalli, which present a general resemblance to those of *Lycopodium annotinum*,[1] are of considerable size, completely devoid of chlorophyll, and fairly well provided with rhizoids, especially round the edge. Their form is that of a thick fleshy cake, which soon becomes thrown into folds by the unequal growth of the margin. The upper surface is concave, owing to the sides becoming turned up at an early stage. The sexual organs are borne on the upper surface; both antheridia and archegonia may be present at the same time. These resemble the sexual organs of other Lycopods. Even after the young plants have attained a length of several inches the large, almost spherical, foot can be distinguished. They are similar to those of *Lycopodium annotinum*; no trace of any organ corresponding to the embryonic tubercle of *Lycopodium cernuum*[2] is visible, and the leaves exhibit a gradual transition from simple scales to the form characteristic of the species. A broad layer of tissue separated from the under surface of the prothallus by one or two layers of cells contains an endophyte fungus, the mode of occurrence of which suggests that it is of the nature of a mycorhiza.

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[1] Fankhauser, *Bot. Zeit.* 1873, p. 1.

[2] Treub, *Ann. d. Jard. Buitenzorg*, 4, p. 131.

6. *Note on the Anatomy of the Stem of Species of* Lycopodium.
By C. E. JONES, *University College, Liverpool.*

Ten species of *Lycopodium* have been examined; among these two types may be distinguished.

1. Type of *L. clavatum* (L.). The oval stelic arrangement is marked by a considerable amount of xylem, broken up into patches by bands of phloem. Centrally these bands are strap-shaped, but at the ends of the long axes the areas of phloem are external, and occur as curved and flattened wedges. Large cells without contents, sieve-tubes, appear in the centre of the strap-shaped bands. Protophloems and protoxylems are external, forming a continuous ring, as figured by Hofmeister; so that, using De Bary's terminology, the arrangement of the bundles is radial. Pericyclar and the so-called endodermal cells occur in concentric zones, 1-3 cells broad. The former swell up, especially in glycerine or glycerine jelly; the latter are generally considerably lignified. The cells of the cortex lying just external to the endodermal cells are thickened and lignified, forming a third concentric zone several cells deep. To this type conform *L. alpinum* (L.), *L. phlegmaria* (L.), *L. dendroides* (?), and *L. cernuum* (L.).

2. Type of *L. squarrosum.* The type which contrasts most markedly with the former is found in *L. squarrosum* (Forst), *L. dichotomum* (Jacq), and *L. nummularifolium* (Blume). The phloems occur as islands in the sea of xylem, or as inserted peninsulas. The phloems are centrally built up, with the apparent sieve-tubes in the centre. Protoxylems are well marked, and lie externally, but protophloems are not to be distinguished. Endodermal cells and pericycle are found as in the previous type. The sclerenchymatous sheath is wanting, or very slightly developed.

The two remaining species, *L. Dalhousieanum* (Spring), and *L. selago* (L.) are, to some degree, intermediate types. The phloem in *L. Dalhousieanum* shows both types, strap-shaped and centric. In the branches the structure becomes simpler. There are two narrow strips of xylem, with an intermediate strip of phloem, so that a prominent row of sieve-tubes occupies the very centre of the stelic cylinder. *L. selago* in its structure is modified on that of *L. clavatum.* An interesting feature of *L. selago* and *L. squarrosum* is the occurrence of root-structures running through the stem. These consist of steles containing a crescent-shaped mass of xylem, with protoxylems towards each tip, while the concave portion is filled up with phloem. A characteristic sclerenchymatous sheath surrounds the stele. In *L. selago* these root-structures are found even above the point where the stem branches, but in *L. squarrosum* they have fused with the central cylinder before branching occurs.

MONDAY, SEPTEMBER 12.

1. A discussion on the Alternation of Generations in Plants was introduced by the reading of the following Papers by Mr. Lang, Professor Klebs, and Mr. Wager.

(*a*) *Alternation of Generations in the Archegoniatæ. By* WILLIAM H. LANG, M.B., B.Sc., Lecturer in Botany at Queen Margaret College, Glasgow University.

[Ordered by the General Committee to be printed *in extenso.*]

One of the most important facts in the morphology of all plants higher than Thallophytes is the occurrence in their life history of two alternating stages, which differ widely from each other both in structure and reproduction. Of recent years advances in our knowledge in several distinct departments of botanical investigation have raised anew the question of the nature of this Alternation of Generations. The subject has been discussed from two very different standpoints in the Presidential Addresses to this Section of the British Association this year and at the Liverpool meeting.[1] These expressions of opinion by Dr. Scott and Professor Bower render an introductory paper to this discussion in one sense superfluous. While, however, repetition of much that has been already said is unavoidable, the existence of such diverse views suggests a slightly different treatment of the question, which may be useful for the purposes of the discussion. Instead of advocating either the theory of antithetic or of homologous alternation, I shall try to present a dissection of the subject; with this object the main facts known as to alternation of generations will be briefly discussed, and the possible interpretations of them considered. The facts will as far as possible be kept apart from the theoretical views to which they have given rise, and the points on which our knowledge is deficient will be emphasised rather than minimised.

The general facts regarding alternation of generations in archegoniate plants can be dismissed very briefly. In all the main groups a definite alternation of a sexual with an asexual generation is found. The latter is normally developed from the fertilised ovum, the former from the spore. The Bryophyta and Pteridophyta are, however, opposed to one another in the relative complexity attained by the two generations. The sporophyte in the Bryophyta remains dependent on the Moss or Liverwort plant, and has as its main function the production of the spores. It may, however, attain very considerable complexity of structure and possess a well developed assimilation tissue. In both Hepaticæ and Muscineæ very simple sporogonia lead on to complex ones in which the sterile tissue of the wall, foot, seta, &c. forms a considerable proportion of the whole structure. The gametophyte, on the other hand, is always independent, and often shows a complicated external form with clearly differentiated stem and leaves. In the Vascular Cryptogams also the gametophyte is always independent, but is of relatively simple form and structure. The sporophyte, which develops from the fertilised ovum, very soon produces roots, and attains independence by the death of the prothallus. It shows a distinction of stem and leaf, is highly organised, and does not develop spores until after a period of vegetative growth. While these points of difference which indicate the great gap between the Bryophyta and Pteridophyta are borne in mind, due weight must be given to the points of agreement. Of these, the similar structure of the sexual organs, the fact that in both the sporophyte is at first dependent on the gametophyte, the presence of stomata and intercellular spaces in the sporophyte, and the similarity in the spore production may be mentioned. A consideration of these facts by themselves indicates no view as to the mode of origin of the two generations. At no stage do the two generations in any Archegoniate closely resemble one another, except in the case of the young plant and the prothallus of *Lycopodium cernuum*. The deviations from the normal life history, which will be considered later, may somewhat modify this statement.

We are justified in assuming that the Bryophyta and Pteridophyta arose from ancient Thallophytes; the study of the life histories of the Algæ and Fungi, which exist at present, may accordingly be expected to aid in arriving at probable conclusions as to the origin of the alternation in archegoniate plants. It is naturally among the green Algæ that indications of this sort might be expected, nor are they wanting, though the precise weight to be attached to them is a matter of uncertainty. The higher Fungi and the Red and Brown Algæ may for the sake of simplicity be left on one side with the remark that in Ascomycetes and Florideæ we see a development which presents analogies with the alternation in Archegoniates. Confining ourselves to the green Algæ and the simpler Fungi we find among them two sorts of phenomena which have been termed alternation of generations. Most of these organisms reproduce both sexually and asexually, and sexual and asexual individuals, resembling one another in their vegetative structure, are often found. The same individual may, however, bear both kinds of reproductive organs, and

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[1] The existence of these recent statements of the problem renders reference to the literature of the subject unnecessary.

Professor Klebs has shown in a number of cases that the mode of reproduction is largely determined by the external conditions, and can be brought under experimental control. There is thus no doubt that these sexual and asexual individuals are homologous in the full sense of the term. But there are a number of Thallophytes in which another stage in the life history is found, which, by its regular recurrence and the position it occupies in the life cycle, suggests a comparison with the sporophyte of the simpler archegoniate plants. While in many Thallophytes the fertilised ovum or the zygospore develops directly into an independent plant resembling the parent, in these it first divides into a number of cells, which are usually motile spores, but may form a small mass of tissue from the cells of which swarm spores arise. It is sufficient to mention *Œdogonium Cystopus* and *Coleochœte* as organisms which show this clearly. In the life history of *Sphœroplea* only sexual individuals and the group of swarm spores, which results from division of the oospore, alternate, independent asexual individuals not being found.

If we now consider how this second form of alternation in Thallophytes might have come about, without for the moment extending our view to archegoniate plants, the essential distinction of the antithetic and homologous theories will become plain. Further, we shall here be dealing with a problem with regard to which the work of Professor Klebs justifies the anticipation that direct evidence will sooner or later be obtained. The main question at issue is, In what relation does the group of spores in *Œdogonium,* or the small mass of tissue resulting from the division of the fertilised ovum in *Coleochœte,* stand to the asexual individuals of the same species? There is some evidence that in this stage we see the representative of an asexual individual, the vegetative body of which has become more or less completely reduced. Thus occasionally in *Œdogonium* a vegetative individual develops from the zygote; in *Uothrix* the zygospore develops a rhizoid, but the contents of what appears to be a rudimentary plant are wholly devoted to the formation of motile spores. On this view the cell mass in *Coleochœte* would be regarded as a reduced thallus, all the cells of which form spores asexually. The reduced generation which proceeds from the zygote would genealogically correspond to an independent asexual individual; and just as the latter is homologous with a sexual individual, so would the four spores in *Œdogonium* or the cell mass in *Coleochœte* be. This would be homologous alternation of generations.

But the same facts can be viewed in another light. In all these cases the advantage to the plant in producing almost at once a number of individuals instead of one as the result of the sexual act is obvious. The division of the ovum may have originated as a special adaptation to this end, and not represent a reduced first neutral generation at all. In the life history of these plants there would then be a stage not represented in the majority of the Thallophytes, which may in this sense be spoken of as interpolated. The cell mass of *Coleochœte* upon this view would not represent a less reduced neutral generation, but a more complicated development of the interpolated stage, which is seen in its simplest form in *Œdogonium.* This stage would not correspond to, or be homologous with, the independent asexual individuals, and leaving these out of account, only one individual, and the result of elaboration of its zygote would be represented in the life history. The alternation would not be homologous but antithetic.

If we now proceed to apply these two points of view to the facts of alternation in the Archegoniatæ the problem in its most general form is this: Is the sporophyte in the Bryophytes and the Vascular Cryptogams to be ultimately traced back to modification of a genealogical individual homologous with the gametophyte, or is it the result of still further elaboration of an interpolated stage more or less like that seen in *Coleochœte?* On the antithetic theory the sporophyte is traced increasing in complexity through a series of forms illustrated by *Œdogonium, Coleochœte, Riccia, Marchantia, Anthoceros*; and the simplest sporophytes of the Vascular Cryptogams are regarded as having been derived from a sporogonium, which already possessed a considerable amount of sterile tissue. If, on the other hand, we apply the homologous theory, several alternatives present themselves. The first, which is not widely different from the antithetic theory, is that in the course of its descent the sporophyte of the Vascular Cryptogams has passed through a stage resembling the Bryophyte sporogonium, but that the origin of this second generation in the ancestral Algæ was homologous. But the homologous theory does not necessarily assume the existence of the sporogonial stage. The sporophyte of the Vascular Cryptogams may have had an independent origin from that of the Bryophyta, and have resulted from the modification of individuals, which were never reduced to the condition of a fruit body.

As to the circumstances which led to alternation of generations, the two theories are in essential agreement. We owe to Professor Bower the general statement, which must serve as the starting point of any explanation, that the origin of the alternation may be correlated with a change of habit from aquatic to sub-aerial life. This holds whether the second generation is considered to be homologous with the first, or to be the result of interpolation. On the latter view, which is that elaborated by Professor Bower, the importance of the drier conditions of life is sought in the prevention of repeated acts of fertilisation. It would thus have been an advantage to the organism to produce many individuals as the result of one sexual act, and this is seen to be effected with increasing perfection as we pass from the simpler to the more complex Bryophyte sporogonia, and from these to the Pteridophyta. The same change of environment may, however, have initiated the modification of individuals, which were originally potential sexual plants, into spore-bearing forms. We shall return to this when discussing apogamy.

We have seen that the facts of morphology do not of themselves indicate decisively which theory is the correct one. The reasons which render one or the other view the more probable are bound up with the more general question of the course of descent in the vegetable kingdom. The question of the relationship between the main groups of plants is a very complex one. All that we need do here, however, is to recognise the existence of several alternative views, and the bearing of these on the two theories of alternation. The indications of alternation in the Thallophytes may be first referred to. These seem closely comparable to the simplest Liverwort sporogonia, but it has not been suggested that any direct relationship exists in any case. The existence of these rudimentary sporophytes in various Green Algæ, in *Cystopus*, and in an analogous, though distinct form in Ascomycetes and Florideæ, is indeed strongly suggestive of their independent origin in the Thallophytes of the present day, and justifies us in considering it probable that similar developments may have occurred in the ancestral Algal forms from which the Archegoniates arose. But the further recognition of the possibility that the origin of the Archegoniatæ may have been polyphyletic, and in particular that the Vascular Cryptogams may have had a line of descent from Thallophytes perfectly distinct from that of the Bryophyta, has a much more important bearing on the nature of alternation. The gap between Bryophytes and Pteridophytes is wide, and on this view would be an essentially natural one; any attempt to bridge it would involve misleading conclusions. I do not wish to enter into the question of the polyphyletic origin of archegoniate plants further than to show that its possibility must be borne in mind in considering the nature of alternation. It may be pointed out, however, that such a view would appear to follow naturally from the supposition that the origin of the sporophyte was correlated with the spread of aquatic organisms to the land. It may be considered probable that a number of organisms in different places would have undergone more or less similar modifications. The homologies which exist between the spore-bearing generations of Mosses and Ferns are no less possible results of homoplastic developments than others in favour of which direct evidence exists. If the origin of the Pteridophyta has not been from the Bryophyta, the comparison between the sporogonia of the latter and the simpler sporophytes of the Vascular Cryptogams would lose much of its weight, since the two may have proceeded, as Goebel suggested, on distinct lines from the beginning. It is therefore advisable to ascertain if any evidence exists which may indicate how the Vascular Cryptogams could have been derived directly from Algal forms. Something of the kind, as we shall see, may possibly be afforded by the facts of apogamy.

So far we have seen no reason to regard the nature of alternation and the views on descent which underlie it as anything but open questions. There are, however, two important classes of facts, which have been regarded as affording more direct evidence in favour of the antithetic and homologous theories respectively. These are the cytological differences between the two generations, and the deviations from the normal life history known as apospory and apogamy.

The first of these will only be mentioned. The existence of the double number of chromosomes, which results from the sexual fusion, in the nuclei of the sporophyte, throughout Bryophyta, Ferns, and the higher plants, certainly appears to lend support to the view that the sporophyte is an interpolated stage in the life history. From the cytological point of view the intercalation is between the doubling of the number of chromosomes by the sexual fusion and the reduction in number in the spore mother cells. Facts are wanting as to the nuclear changes in Thallophytes, and also in apogamy and apospory.

These latter phenomena are the last element in the problem that can be referred to at length. We saw that in the case of the alternation of clearly homologous generations in the Thallophyta it had been shown that the assumption of the sexual or asexual form depends on the external conditions. This experimental study needs to be extended to the rudimentary sporophytes of the Green Algæ, but with regard to these it is already known that in *Œdogonium* the fertilised ovum may grow out directly into a vegetative plant, instead of dividing into spores. In the Archegoniatæ this complete substitution of one generation for another is not known to occur; no variations in the external conditions are known to induce a Fern spore to develop into a Fern plant, or the fertilised ovum to give rise directly to a prothallus. But the facts as to the direct development of the one generation from the tissues of the other, and the existence of structures which may fairly be described as intermediate between gametophyte and sporophyte are sufficiently striking.

The main facts with regard to apospory, the vegetative origin of the gametophyte from the tissues of the sporophyte, are briefly these. In Mosses cut portions of the seta or capsule have been induced to give rise to protonemal filaments; in one case this is known to have occurred in nature while the capsule was still attached to the Moss plant. In a number of Ferns the production of prothalli from the sporangia, the placenta, the surface of the leaf or the leaf margin, takes place. In *Scolopendrium vulgare* and *Nephrodium Filix-mas* varieties are known in which the first leaves of the young sporophyte exhibit this capability of producing prothalli. The causation of this phenomenon is still obscure. In a number of cases sporal arrest has been shown with probability to be of importance, notably in the case of *Onoclea*, in which apospory occurred on fertile leaves which had been experimentally induced to assume the vegetative form. Further, the fact that conditions of life favourable to the gametophyte, such as laying the fronds on damp soil, determine the growth of prothalli from the tissues of some aposporous Ferns may be mentioned. As to the weight to be attached to apospory it must be borne in mind that the phenomenon is little more wonderful than the fact of the spore, a cell isolated from the sporophyte, producing a prothallus. Here, as in the case of apogamy, the investigation of the cytological details is urgently needed.

The deviations from the normal life history, which are classed as apogamy, may be considered to possess more importance as suggesting the homology of the two generations in the Ferns. Though as yet only known in this group of plants, apogamy has been found in more than twenty species. In some the young Fern-plant arises on the under surface of the prothallus, which in these cases often bears few or no sexual organs. But in cases in which apogamy has been induced the characters of the two generations may be much more intimately blended. Thus tracheides may occur in a prothallus more or less modified in external form. This may grow on as a bud, or may bear isolated members of the sporophyte, leaves, roots, ramenta, or sporangia. The characters of the two generations are here united in the same individual in a way that at least suggests a gradual transition from gametophyte to sporophyte.

It is to be hoped that the further study of these deviations from the normal development will lead to their causation being made clear. This may minimise the importance to be attached to them, especially should they be found to depend on a nuclear change. The facts regarding the cytology of these new growths are still unknown; it is not even certain that the cells of the aposporously produced prothalli possess the half number of chromosomes, and those of the apogamously produced sporophytes the double number, though this may be assumed to be probable. Apospory at least might be readily explainable by such a nuclear change.

With regard to apogamy, however, some general conclusions may fairly be drawn even in the absence of observations on the nuclei. For whatever change may take place in the latter, it is certain that the transition from prothallus to sporophyte, or from prothalloid to sporophyte tissue, takes place without relation to the sexual fusion, and is so far comparable to an ordinary variation. Further, it is to be noted that the change takes place, so far as the conditions are known, when, by preventing the access of fluid water, fertilisation is delayed, and when in other ways the conditions approach those favourable to the sporophyte rather than the gametophyte. These modifications of the conditions are of the kind to which aquatic organisms would be exposed on assuming a terrestrial habit. It is, therefore, possible to view the changes which take place in prothalli under these circumstances, not as reversions, but as indications of the capability of the gametophyte to assume the characters of the sporophyte under suitable conditions. If there is any truth in this way of regarding the facts of apogamy, they become of value in enabling us to picture the steps by which the Fern sporophyte may have arisen by changes in individuals homologous with the original sexual form. The prothallus, especially in the Ferns, must have departed much less widely from the ancestral Algal form than the sporophyte; this may be connected partly with the conditions to which it remains adapted, and partly with the fact of its growth being in nature cut short by the early formation of the embryo upon it. The various cases of apogamy which have been observed form an almost complete series of transitions between prothallus and sporophyte, and have been used to frame a provisional hypothesis of how the alternation in the Ferns might have arisen, if it did not come about in the way suggested by the antithetic theory.

All such use of the facts of apogamy and apospory is liable to the criticism that they are teratological in their nature, and are not a safe guide in a morphological question of this sort. There are many facts which go far to justify such a view, but we should, I venture to think, be unwise to leave the consideration of these phenomena altogether on one side. Not only can no sharp line be drawn between variations (the use of which in evolutionary questions none will deny) and monstrosities, but, apart from the particular organic forms which result, we appear to be dealing with a capability of many—perhaps all—Fern prothalli to assume characters of the sporophyte; a general property of the gametophyte of this kind cannot be disregarded. A fuller knowledge than we possess of the causes of apogamy is, however, necessary before the bearing of the phenomenon on the nature of alternation can be properly estimated; such knowledge may lead to an explanation more in accordance with the antithetic theory than any which has yet been given.

Whether the homologous or the antithetic theory is to be considered the more probable has an obvious bearing on morphology. But there is a wide difference between considering the two generations homologous with one another in the sense that the spore-bearing generation is ultimately to be traced back to modification of the sexual, and the view that any special structure of the sporophyte is strictly homologous by descent with any structure in the gametophyte. Special evidence would be necessary before such a conclusion could be drawn, and, so far as I am aware, no such case has been shown to exist. Not only, then, does the question of the nature of alternation of generations in the Archegoniates appear to be an open one, but there seems no reason to apprehend confusion in comparative morphology, whichever of the two theories be adopted as a working hypothesis.

In concluding this account of some of the main factors in the problem which is the subject of this discussion, three subsidiary questions may be suggested—the probable line of descent in archegoniate plants, the bearing of the cytological facts on the question, and the significance to be attached to apospory and apogamy. None of these questions, any more than the general one of the nature of alternation, may admit of a decided answer. It can, however, hardly fail to be productive of good if this discussion enables us to see our way more clearly to the directions in which the answers to these problems must be sought.

(*b*) *On Alternation of Generations in the Thallophytes.*
By Professor GEORG KLEBS.

[Ordered by the General Committee to be printed *in extenso.*]

Since the pioneering investigations of Hofmeister it has been generally recognised in Botany that the Archegoniatæ are characterised by a definite form of alternation of generations. It consists in the regular alternation of a part which bears the sexual organs—the gametophyte—and of a non-sexual part which produces the spores—the sporophyte. An essential difference separates the two divisions of the Archegoniatæ. In the Pteridophyta the gametophyte is a delicate, short-lived, thalloid structure, the sporophyte is a well-developed, leafy plant. In the Bryophyta, however, the gametophyte appears as a leafy plant, while the sporophyte is represented by a leafless stalked capsule, which lives as it were parasitically on the gametophyte.

In sharp contrast to the harmonious unanimity which has hitherto been the rule in Botany as regards this alternation of generations in the Archegoniatæ is the lively contest of contradictory views as to the alternation of generations in the lower plants. With regard to these the question arises, first, whether a regular alternation of definitely characterised generations is to be observed, and secondly, what in that case is the connection between this alternation, should it turn out to be a fact, with that of the Archegoniatæ. I shall not deal exhaustively here with the many different opinions on this question; I shall briefly touch upon those views only which are important in point of principle.

The first clear carrying out of the idea of a regular alternation of generations in the Thallophytes is in the Text-book of Sachs (1876), who there endeavoured to make the course of development of Algæ and Fungi fit with that which holds in the Mosses. The life of *Vaucheria, Mucor*, an Ascomycete, or one of the Florideæ, is divided according to Sachs into two sharply separated parts, of which one is characterised by the appearance of sexual organs, the other by the spore-bearing tissue which springs from the fertilised ovum. Thus the mycelium of a *Mucor* which bears the sexual organs, the thallus of *Vaucheria*, or of the Florideæ, represents what we now term the gametophyte; the fruit body of Ascomycetes, or of Florideæ, the zygospore of *Mucor*, the oospore of *Vaucheria*, represent the second non-sexual generation—the sporophyte. The alternation of generations of the Thallophytes is therefore according to Sachs essentially similar to that in the Archegoniatæ. The propagation by zoospores, conidia, etc., corresponds to the propagation by buds in the Mosses and Ferns, and is not taken into account as regards the actual alternation of generations.

Pringsheim takes up a quite opposite point of view (1876, 1878). According to his opinion the fruit of the Ascomycetes and Florideæ has not the value of a special generation, but is only to be regarded as a part of the mother-plant sexually influenced. The true alternation of generations of the Thallophytes consists, according to Pringsheim, in the regular succession of independent so-called neutral generations, having non-sexual propagation, and a single sexual generation. Thus, zoospore-forming generations of *Vaucheria*, or *Ædogonium*, alternate with a generation which bears the sexual organs. Both kinds of generations are of essentially similar structure; they are distinguished by the form of their propagation. Only the first generation, which springs from the fertilised ovum, has often properties which differ from those which follow, *e.g.* in *Coleochæte.* In the Mosses this first non-sexual generation is much more sharply characterised; it is developed as the sporogonium, and is the only neutral generation; it differs from the sexual generation only by the scanty development of the vegetative part.

While the views of Sachs on the one hand, and of Pringsheim on the other, were showing some tendency to spread, other views appeared in opposition now to one, and now to the other. Vines (1877) held that most of the Thallophytes have no alternation of generations at all, since their mode of propagation, whether sexual or non-sexual, is directly dependent upon external conditions; that a definite alternation of generations, comparable to that of the Mosses, is only found in *Coleochæte* and *Chara.* Celakovsky (1877), however, was more in accordance with Pringsheim in his conception of the Thallophytes, for like him he accepts an alternation of neutral and sexual generations. Celakovsky designates this alternation of generations as homologous, since the successive generations are equivalent to one another. Celakovsky opposes Pringsheim in his conception of the alternation of generations in the Archegoniatæ, which he designates as the antithetic. Here the two alternating generations are not homologous, but essentially different; the non-sexual generation has also phylogenetically nothing to do with the neutral generations of the Thallophytes. This conception of Celakovsky was at first neglected, but was taken up again by Bower (1890), and put on a footing of detail. Bower holds that the antithetic alternation came about by the intercalation of the non-sexual generation, the sporophyte, as a quite new development between two gametophytes. This interpolation of a special sporophyte probably took place in the alga-like ancestors of the Archegoniatæ, as they passed from a life in water to a life upon the land. In the series of the Thallophytes there are, in addition to the homologous alternation of generations, more or less advanced beginnings of an antithetic alternation, as for instance in *Coleochæte,* the Ascomycetes, and Florideæ.

All the various conceptions of alternation of generations in the Thallophytes rest on morphological comparison of the hitherto known facts of the life history, while still very little was known of the behaviour of these organisms in open nature, or in long continued cultures. Yet by such observations only is it possible to decide whether an alternation of generations can be proved at all, and how the influence of the outer world, so often assumed, really affects the course of life of the Thallophytes. These questions were the point of departure for my investigations on the conditions of propagation in the Thallophytes. The investigation had to be extended in two directions: in the first place, it was necessary to decide whether there is a regular alternation of free and independent generations; secondly, whether a non-sexual generation characterised by special qualities arises of inner necessity from the fertilised ovum.

The first question receives its answer, according to the results of my investigations, that no regular alternation of neutral and sexual generations exists in any of the Thallophytes which have been tested. They possess two or several kinds of propagation, each of which is directly dependent upon quite definite external conditions. If we take any vegetative stage we please, a filament of a *Vaucheria,* an *Œdogonium,* a piece of mycelium of a *Sporodinia* or *Ascoidea,* there are then present in each part the specific potentialities of sexual and non-sexual propagation. In open nature the fortuitous conditions determine which of the potentialities is developed, and how the modes of propagation follow one another, whether upon the same individual, or on different individuals. An exact knowledge of the conditions gives the experimenter the secure control over the organism, which can at will be forced into any desired mode of propagation within the limits of its species. The problem becomes more complex if other additional modes of propagation appear, as they do in many Fungi. In *Saprolegnia* we can distinguish four kinds of propagation: (1) by simple mycelial growth, that is, by breaking of the mycelium into pieces; (2) by zoospores; (3) by oospores; (4) by gemmæ. The conditions for each of these four kinds of propagation are somewhat different, and it is thus possible, as my later investigations prove, to force the fungus at will into one or other of the four modes of propagation.

The potentialities for the several kinds of propagation in the Thallophytes, such as *Vaucheria, Œdogonium, Chlamydomonas, Sporodinia, Saprolegnia, Eurotium,* &c., are quite equivalent, *i.e.* there is no cause in the inner nature of the cell, or in the special organisation of the potentiality, for one of these of its own initiative being developed earlier or later; nevertheless, according to the species, the special conditions which dominate the kinds of propagation may be more or less readily realised in open nature, as well as in the laboratory. In particular, the sexual propagation is often dependent upon more complex conditions than the non-sexual. While both can be induced without difficulty in *Sporodinia*, in other Mucorini it is most difficult to see the zygospores at all. I have not succeeded in my attempts to induce the formation of zygospores in the common and easily cultivated *Mucor racemosus*, though such formation doubtless exists.

In the works of Brefeld the idea is often expressed and tested, of bringing a Fungus by culture through the most numerous successive conidium-forming generations to its higher fruit-form. This idea is connected with Brefeld's idea that inner causes are more important than external causes for the appearance of the fruit-form. The result of the serial-cultures of Brefeld, whether positive or negative, was under all circumstances accidental. The experiments would prove the view of Brefeld only if the external conditions had really been always the same in all the numerous serial cultures. Since Brefeld, to judge from the meagre statements of his methods of culture, has not paid any attention to this constancy of the conditions, it will also have been a matter of chance whether they remained the same, or varied in such a way that another form of fruit took the place of that which preceded it. In any case, I may assert that if in Fungi such as *Sporodinia, Saprolegnia, Ascoidea, Eurotium,* those external conditions are maintained constantly which are characteristic for one of the forms of propagation, that same form only is produced. Hitherto a vegetative growth of whatever duration, or a continued propagation in one form, has never of inner necessity led to the appearance of another.

We can now say that the majority of Algæ and Fungi will behave like the species which have thus far been tested; in which behaviour the relation of dependence of the propagation, on each occasion, upon the outer world will vary extremely according to the species. If one recognises thus far as operative factors, light, temperature, moisture, oxygen, chemical composition of the nutritive medium, here is already at hand a great wealth of most various combinations of external stimuli, which set the formative processes in motion. Further investigation will teach what a wealth of unexpected relations is here to be discovered between the outer world and organic life.

Despite all this the possibility remains that in certain species a regular alternation of neutral and sexual generations does appear. That might be possible for the Florideæ, in which the tetraspores and carpospores are often formed on special individuals. This simple fact proves nothing as yet, since it is faced by the other fact, that both kinds of propagation also appear from the like individual. The question remains open whether the tetraspores do not make their appearance at times, and seemingly on individuals other than do the carpospores, for the simple reason that the external conditions for the two of them are very dissimilar. The question cannot be decided till longer-continued cultures of the Florideæ have been arranged. The answer will presumably not turn out differently from that in the case of other Algæ. At the first glance an alternation of generations in Pringsheim's sense comes to much clearer expression in certain parasitic Fungi, especially in the Uredineæ. If we leave aside the undecided question as to the occurrence of a sexual act, the observations and experiments teach that the life of a Fungus such as *Puccinia graminis* necessarily takes the course of the alternation of two independent generations living upon different host plants, the one bearing teleutospores, the other forming æcidia. In addition there are still the subsidiary fruit formations of the uredospores and of the spermogonia. In fact we have here a regular alternation of generations, such as appears in analogous form in the case of several of the lower animals; there is no obvious reason for avoiding the expression in this case, if one takes into account the actual circumstances of the case. But still it would be wrong to apprehend this alternation of generations as if we had here an essentially new process, as against those other sorts of Fungi which are dimorphic or polymorphic. There are nearly allied Uredineæ in which all the spore forms appear one after another upon the same mycelium. In my view the condition for the different kinds of propagation will also be unlike, and the regular alternation of the fruit forms would be explained by the fact that by the development of the host-plant itself, as by its dependence upon the seasons, changes in it necessarily go forward, which will serve as direct occasion for the growth of the different spore formations of the parasite.

In *Uromyces Polygoni*, for instance, the æcidia appear only on the young plant, the uredospores and teleutospores on the older. In the heteræcismal Uredineæ, the special conditions for the individual fruit formations are much more strongly distinguished still, so that other host-plants are necessary to bring the Fungus to the formation of æcidiospores or teleutospores. The time will probably come when these conditions may be more accurately recognised, and the Uredineæ be cultivated on artificial substrata. Then it will appear whether these parasites do not behave just like the other Fungi, and cannot also be compelled to produce the different fruit formations upon the same mycelium. A great obstacle to the cultivation of the Uredineæ lies in our ignorance of the chemical composition of the host-plants. We are quite ignorant of the substances characteristic for the species, which, besides the usual food-stuffs, sugar, proteid, &c., are at any rate of decided importance for the development of the parasite.

In all the cases now mentioned we have to do with the alternation of several generations, each of which is characterised by special propagation. In the unicellular Thallophytes the non-sexual propagation coincides with the vegetative division. The propagation of the Desmidiaceæ and Diatomeæ by division corresponds to the propagation of *Chlamydomonas* by means of motile cells. In all of them the sexual process ensues after a series of divisions. Naegeli includes these processes under his conception of alternation of generations, and even extends it to the Bacteria in which, after a series of generations by division, the cycle is closed by the formation of endospores. But if the term alternation of generations be limited to organisms with dimorphic propagation an alternation of shoots might be spoken of in this case.

Under all circumstances, whatever name the thing may bear, we must ask ourselves the same question as regards these phenomena as in the dimorphic Thallophytes; we must inquire whether a more or less definite number of cell-generations must be passed through before the fruit generation can follow. In the bacillus of anthrax (*Bacillus anthracis*), Buchner (1890) has already proved that it can be propagated as long as you please by division, and that at any moment the formation of spores can be induced by direct influence of the outer world. Schreiber (1896), who has closely investigated the conditions of spore-formation in several Bacteria, has been able to prove still more definitely that the spore-formation always begins as a direct consequence only of external conditions. Starting from the germinating spore, it was possible, after the third division, to induce spore formation again. In *Chlamydomonas*, I was able to prove with certainty that the cells, through innumerable generations, propagated in an exclusively vegetative manner, but that at any time the formation of sexual swarm spores can be attained with ease and certainty. Most probably the same holds for the Desmidiaceæ, in which certain species may be propagated for many weeks together by division, but from the first were capable of sexual propagation when exposed to the conditions characteristic for it.

On the other hand, the Diatomeæ seem to have a necessary alternation of generations, just as, according to the investigations of Maupas, the Ciliatæ among the Infusoria. According to the theory founded by Pfitzer, the cells of the Diatomeæ, whose silicified cell-wall consists of two parts fitted one within the other, do not grow in the direction which is usually styled longitudinal. The consequence of this is that on each division one of the daughter-cells maintains the length of the mother-cell, the other will necessarily be smaller by the thickness of the membrane. Thus by continued divisions the cells become smaller and smaller till, on reaching a certain minimum size, the process of auxospore formation appears, by which the original maximum length is again attained. This generally acknowledged theory has been supported by the investigations of Miguel. He cultivated a number of diatoms in artificial nutritive media, and noted in the successive generations a gradual lessening of the cells, till finally the formation of auxospores followed very freely. Thus, according to the statements of Pfitzer, Miguel, and others, the view might appear to be sufficiently established, that in the Diatomeæ the formation of auxospores follows only as a consequence of that organisation of the cell which has been described after a number of divisions which may be almost mathematically defined, while the external conditions play no definite part in the process. But, meanwhile, we ought not to forget that this theory is in much need of further confirmation. The main point in the whole question is whether the cell-wall of both cells after division really does undergo no increase by growth in length to even a very small degree. Pfitzer himself has noted that such growth does occur in certain species, though this would be of no account for making up the loss of size which accompanies division. It ought to be distinctly proved, by direct and exact measurements, whether a growth in length takes place or not; above all, we ought to know precisely what influence the various external conditions exert upon the life of the Diatomeæ. It may possibly be that under certain circumstances growth takes place, under others not. The fact, brought forward by Miguel and others, that it is by no means always the smallest cells which form auxospores, but also those of middle size, deserves consideration. Still more important are the statements made by Karsten, that *Melosira nummuloides* can be brought to the formation of auxospores simply by change of water, that in *Achnanthes longipes* the impending conjugation does not take place, but is replaced by vegetative growth when the cells are exposed to a cool temperature. If we assume that definite external conditions induce growth in length during division, others encourage auxospore formation, the earlier observations on the smallness of the cells which form auxospores may thus be explained. In many Thallophytes the rule holds that in the stage of preparation for the higher fruit-form growth diminishes, or ceases, but division is still continued, so that, for instance, in the Desmidiaceæ, *Spirogyra*, and *Chlamydomonas*, it is always the smallest cells which conjugate. This may also be the case on the formation of the auxospores of the Diatomeæ, and the smallness of the cells would then be less the cause of the auxospore formation than the result of those external conditions which occasion this process. I bring this possibility forward in order to draw attention to the pressing need for accurately defining the conditions of the events in the life of the Diatomeæ by the help of pure cultures, and by the use of physiological methods. Whichever way the decision may fall, the life-history of the Diatomeæ gives no explanation of the wholly different alternation of generations of the Archegoniatæ, any more than does that of the other Thallophytes which have been mentioned.

But now the question arises whether there is not in many Thallophytes another form of alternation of generations, which presents nearer relations to the phenomena in the Archegoniatæ. The fertilised ovum develops according to the statements of investigators in a definite way in certain species: thus, for instance, the zygospore of one of the Mucorineæ, the oospore of *Vaucheria*, and *Saprolegnia* usually germinates by formation of a short tube, which directly bears a sporangium. Pringsheim speaks, in such a case, of the first neutral generation: we might regard this as the actual spore-forming generation, corresponding to the sporophyte of the Mosses. Closer investigation shows that an oospore of *Vaucheria* shows no tendency in any way fixed by heredity to form a sporangium. It produces first a short germinal tube, which may either continue its vegetative growth, or may at once form zoospores, or sometimes sexual organs. That would depend alone on external conditions. De Bary and I myself have lately proved the same for the oospores of *Saprolegnia*, and Van Tieghem for the zygospores of the Mucorini. There is no true meaning in speaking of an alternation of generations in these cases, since the formation of the sporangia is not a peculiarity of germination, but follows the same conditions as it does subsequently. These plants do not behave differently in principle from the Fucaceæ, or Conjugatæ, in which the fertilised ovum passes more or less directly into the thallus, since no other propagation exists at all.

But there are perhaps other species in which the mode of germination of the oospores has become more definite. The zygotes of *Hydrodictyon* show, according to Pringsheim, a characteristic mode of germination, but it is not yet known exactly how far it is a constant process. In *Œdogonium* the germinating oospore forms four zoospores—a process which does not occur again in its later life. The manner of germination is not absolutely indispensable, since the oospore also passes over directly into a filament, though it appears to be the commoner case. Still more peculiar is the germination of *Coleochæte* as described by Pringsheim, in which the fertilised ovum divides and forms a tissue, from the cells of which zoospores arise, which then grow on into the typical thallus. There are no exact investigations whether this kind of germination is a constant phenomenon, since the germination has only been observed by Pringsheim, under conditions which were apparently not very favourable. The formation of these bodies, which are like the zoospores formed elsewhere, from the tissue of the oospore, is perhaps a quite fortuitous circumstance, which differs in no way from the usual propagation. But the chief reason for comparison with the Mosses, and for the assumption of an alternation of generations, lies in the production of specially formed propagative cells from the oospore. It might be quite possible that the cells of the oospore in *Coleochæte scutata* should pass over directly in to the thallus, but in *C. pulvinata* perhaps only after a change in the mode of growth. The essentially regular germination by help of a pro-embryo, as in *Chara*, will not be accepted as a formation of a special non-sexual generation. It is true that Vines has advanced such a conception, and compares the pro-embryo of *Chara* with the whole sporogonium of the Mosses. His view has not been taken up, since as a matter of fact in *Chara* a comparison seems permissible only with the protonema of the Mosses, or with the pro-embryo of *Batrachospermum*.

Next to *Coleochæte* it is the Ascomycetes and Florideæ, the life history of which has since the time of Sachs been compared with the alternation of generations in the Mosses, for in both the fertilised ovum has often a complicated development of its own; the last object of this is the formation of spores, which are clearly different from the usual propagative cells. As described by Schmitz, and according to the latest observations of Oltmanns (1898), the nature and method whereby the formation of the fruit depends on an intimate union of the fertilised egg-cell with definite auxiliary cells of the mother-plant is extremely peculiar. In the higher differentiated forms, *e.g. Callithamnion*, according to Oltmanns, a cell-derivative from the fertilised egg-cell—a cell-nucleus with some protoplasm—is united with a large auxiliary cell, and coalesces with it into a new cell-unit, whereupon the nucleus of the auxiliary cell is pushed aside as apparently functionless. This new cell, of which the wall and of which the plasma belong for the most part to the mother-plant, is stimulated by the 'egg-energid' to form the spores. In still more highly developed forms the mother-plant provides also for the enveloping of the spore-producing cells. Oltmanns compares the relation of egg-cell and mother-plant with that of a parasite and its host-plant, and sees therein a confirmation of the view that the fruit of the Florideæ corresponds to the sporogonium of the Mosses. But one may also designate the state of the facts with this expression: that the fruit of the higher Florideæ is a product of the mother-plant that is stimulated by the fertilised egg-cell. Pringsheim, at least, might, in the far-reaching dependence of the fruit formation upon the mother-plant, find a substantial support for his view, that the fruit of the Florideæ has not the value of a special non-sexual generation. Finally we have to consider subjective interpretations. I myself should hold the comparison of the Floridean fruit with the sporophytes of the Mosses as quite justified. But one essential point in this matter ought not to be forgotten. One may compare the fruit of the simple Florideæ with that of the simple Liverworts, and apprehend both as in some degree analogous structures. But a very important and interesting difference discloses itself, if one follows up the line of development in the two series. In the Mosses the effort is distinctly marked in the ascending series of forms to differentiate more highly the sporogonium as an immediate product of the fertilised ovum, and to make it more independent of the mother-plant in its nourishment. In the series of the Florideæ the opposite tendency shows itself to make the development of the fertilised ovum constantly more strongly dependent on the mother-plant, and to attain the higher differentiation of the fruit by means of essential co-operation of the mother-plant. Beyond this no one will wish to assert a nearer relation of kinship between Mosses and Florideæ.

It is still more difficult in the Ascomycetes to decide the question of the alternation of generations than in the Florideæ. Notwithstanding the remarkable differences which are to be observed in them up to the origin of the ascus fruit, we must still, with De Bary, regard the whole group as a single and united one. But we ought not to connect the Ascomycetes with the Phycomycetes, either with the Peronosporeæ after De Bary, or with the Mucorineæ after Brefeld; but we should recognise in them a group which, with its simplest forms, sends out its roots into the lowest division, the Archimycetes, to which the Chytrideæ and other Fungi belong. In quite simple Ascomycetes, *e.g. Ascoidea*, *Dipodascus*, *Endomyces*, there appears a striking difference in the mode of origin of the asci. In *Ascoidea* and *Endomyces*, according to Brefeld, each ascus arises directly from a mother-cell of the mycelium. In the nearly related *Dipodascus*, according to Lagerheim, two cells coalesce, and it is the product which grows on into the ascus. In the one case—apparently the more common one—the ascus is a direct product of the mother-plant; in the other forms we may speak of the beginning of a non-sexual generation. If we pass on to the fruit-bearing forms in some still relatively simple species we find the asci as products of a fertilised ovum, *e.g.* in *Sphærotheca* according to Harper, or the Laboulbeniaceæ according to Thaxter. In others we may regard a structure homologous with the ovum, but not actually capable of fertilisation, as the starting-point for the formation of asci, while other constituent parts of the fruit, such as the wall, and commonly the stalk, &c., are supplied by the mother-plant. In the highest forms the most complicated Pyrenomycetes, and the *Cladonias* among the Lichens, &c., the fruit is, according to our present knowledge, exclusively a product of the mother mycelium, just as is the case according to Brefeld in the Basidiomycetes. It is only in case of the simpler forms that we can compare the ascus fruit with the sporogonium of the Mosses, and, as Oltmanns has done, place it in relation to the processes in the Florideæ. In the Ascomycetes it is still more clearly to be recognised than in these plants that the antithetic alternation of generations has stood still at the first attempts, and in the higher forms has been replaced by direct development of the fruit from the Mycelium. As regards the solution of the question how the alternation of generations in the Archegoniatæ came into existence the Ascomycetes can contribute far less than the Florideæ.

Taking a general view of the department of the Thallophytes thus traversed, the following cases may be distinguished as relating to the question of the appearance of an alternation of generations:—

1. The majority of the Algæ and Fungi have two or more kinds of propagation, each of which necessarily depends upon definite external conditions characteristic for it. According to the conditions, occurring fortuitously in open nature or in cultivation, the kinds of propagation may appear on the same or on different individuals, independently or in any succession. The fertilised ovum in sexual forms does not differ essentially on germination from another propagative cell. In none of these cases is there any reason for speaking of an alternation of generations.

2. In certain heteræcismal parasites, *e.g.*, many Uredineæ, the life-history of the species takes the course of a regular succession of different individuals with special modes of propagation; we may here speak of an alternation of several generations characterised by different propagation. There would be in this case an alternation of homologous generations in the sense of Celakovsky and Bower. Here, also, we have essentially to deal only with Fungi which have dimorphic or polymorphic propagation, with the limitation that the external conditions for some of the forms of propagation are so different that, so far as experience yet goes these are only developed upon separate host-plants.

3. In the unicellular Diatoms there is, according to the theory of the cause of auxospore formation hitherto current, an alternation of generations in the sense that, after a definite number of cell-generations derived by division, the formation

of auxospores follows by internal necessity. But it needs still more exact investigation, for it is quite possible that the formation of auxospores, like the formation of zygotes of the Desmidiaceæ, is essentially dependent upon external conditions. In that case there would be no definite alternation of generations in the Diatomeæ.

4. In a number of Thallophytes, some few Chlorophyceæ, above all, in the Florideæ and Ascomycetes, a fruit arises from the fertilised ovum, or a body homologous with it, which produces, in a manner peculiar to it, non-sexual cells, the spores. This spore-bearing fruit may be compared with the sporogonium of the Mosses, and the alternation of the sexual plant with the spore-fruit may be regarded as an antithetic alternation. But this comparison does not extend further than the establishment of a certain analogy.

In the two series of the Florideæ and Ascomycetes, in contrast to the series of the Mosses, it appears that the fruit in the higher forms becomes constantly more dependent upon the mother-plant, and that the duty of higher differentiation of the fruit falls essentially upon the latter. The fruit there appears not as a special generation, but as a product of the mother-plant.

What, then, remains from which to derive the alternation of generations of the Mosses and Ferns? Only *Coleochæte*, which, since Pringsheim's celebrated investigation, has been quoted as a connecting link between Algæ and Archegoniatæ. But it has never been proved that the zoospores of the germinating oospore are to be regarded as a characteristic product of the fruit, and, accordingly, as a form of propagation homologous with the Moss-spores. But, on the other hand, it makes no great demand on our imagination to figure to ourselves how, in the *Coleochæte*-like ancestors of the Mosses, this step was taken, that then the second step consisted in the formation of stationary spores arising by a tetrad division. With such assumptions, the transition to the simple Liverworts—e.g., *Riccia*, does not appear very great, and, starting from this form, the different series included in the Bryophyta may be derived. Though we have thus gained certain connecting points for the phylogeny of the Mosses, the question as regards the Ferns, in which the fertilised ovum develops into the leafy plant, is in quite another position. It has been recognised on many sides how great a contrast there is between Mosses and Ferns. The common peculiarity in the structure of the Archegonium might be a purely parallel development without its necessarily indicating any phylogenetic connection. It is not my purpose to enter now upon these difficult questions, the less so since they will be dealt with here from an official quarter. They deal with the most interesting, but also the most obscure, points in the phylogeny of the vegetable kingdom. For the spot where the first indication of a Fern-sporophyte appeared was the birthplace of the vastly-developed series of the Phanerogams. The Thallophytes hitherto known do not give the least clue to the discovery of that spot.

(c) *The Formation of the Zygospore in* Polyphagus Euglenæ.

By HAROLD WAGER.

1. This rare organism is found as a parasite on *Euglena viridis.* The material for this investigation was found with Euglenæ on a filter bed at Keighley in Yorkshire, and cultivations were made in which the methods of spore formation and zygospore formation were observed from the beginning to the end.

2. The vegetative cell contains a single nucleus of large size and somewhat peculiar structure.

3. In the process of zygospore formation a rhizoid from the receptive cell comes into contact with the discharging cell. The latter is nearly always larger than the former, and contains a larger nucleus.

4. The end of the rhizoid in contact with the discharging cell swells up and becomes the zygospore. The small nucleus from the receptive cell passes into it first of all together with the protoplasm, and then the large nucleus of the discharging cell makes its way through the opening between the cells into the zygospore also.

5. The two nuclei come into close contact with one another, but do not fuse.

They separate from one another again, and the smaller nucleus then increases in size until it attains the same proportions as the larger nucleus.

6. At a very late stage in the development of the zygospore two nuclei can still be observed, but there are indications that these two nuclei fuse together at a still later stage.

The following Papers were also read :—

2. *On the Peltation of Leaves.* *By* Professor C. DE CANDOLLE.

The object of the present paper is a comparative study of peltate leaves, with special reference to the number of species possessing such organs, their distribution amongst the various natural orders, and their respective mode of growth.

Pitcher-shaped leaves—that is to say, natural ascidia—are here considered as being homologous with ordinary peltate leaves, a view long ago sustained by Baillon and based on the organogeny of both sorts of leaves. Accordingly, by the general expression of *peltation of leaves,* the author includes peltate leaves proper and ascidia.

As the result of bibliographical researches the author has succeeded in cataloguing 308 phanerogams having peltate leaves proper and 49 having ascidia-shaped or ascidia-bearing leaves. A general survey of all these cases of peltation has led him to the following results :—

1. The peltation of leaves is very rare, the species in which it has as yet been observed being an insignificant minority in the total number of actually known phanerogams, estimated at about 110,000 species.

2. The peltation of the leaflets of compound leaves is still more exceptional, only two such cases having so far been recorded—namely, in the genus *Thalictrum.*

3. Peltate leaves proper and ascidia-shaped leaves are unknown amongst verticillate and extremely rare amongst opposite leaves.

4. Sarraceniaceæ and Nepenthaceæ being placed on one side, the peltation of leaves is always an exceptional character in each order or genus in which it occurs. Cases of peltation appear, so to say, at random in various natural orders, between which they are very unequally distributed. Consequently there is no correlation between the peltation of leaves and the floral characters of plants.

5. While there is an evident functional adaptation of ascidia-shaped leaves to the biology of the plants which produce them, peltate leaves proper on the contrary do not seem to possess any such adaptation, so that they must, for the present, be looked upon merely as an indication of an excess of development not as yet accounted for.

6. The great scarcity of peltate or ascidia-shaped leaves amongst actual phanerogams is difficult to reconcile with the fact that teratological ascidia are of rather frequent occurrence.

7. The peltation of leaves is in no correlation with the geographical distribution of plants. However, phanerogamic species in general being immensely more numerous in the inter-tropical than in the extra-tropical regions, peltate-leaved plants are necessarily also much more numerous in the former than in the latter zones.

3. *Changes in the Sex of Willows.*
By I. H. BURKILL, *M.A.*, Royal Gardens, Kew.

In the genus Salix flowers of both sexes are occasionally present in the same catkin, and one sometimes finds that the sexual organs are intermediate in structure between stamens and carpels. By using the published records and by availing myself of the large accumulation of material for study in the Herbaria at Kew, Cambridge, in the British Museum, and at the Jardin des Plantes, Paris, I have gathered together a number of facts which may be of interest.

Firstly, it is obvious that these abnormalities, though widely distributed in the species of Salix, are much more common in some sections than in others. The

§ *Capreæ* yields by far the greatest number; and second to it comes the § *Fragiles.* In dwarf willows they seem to be very rare, and in § *Glaciales* I have only found one abnormal catkin.

Secondly, we notice that, though the two-staminal willows yield most freely these abnormalities, those in which the male flowers possess more than two stamens sometimes show them. I can instance *S. pentandra* and *S. humboldtiana.*

That the male organs or the female organs are produced from the same rudiments is extremely probable; and in the normal Salix we have an unisexual flower, which cannot, as in most Phanerogams, be shown to have had an origin from a hermaphrodite flower by abortion of one sex. In these abnormal willows, while we readily follow the change of the two stamens of one of the *Capreæ* or *Purpureæ* into the two carpels, it is not so easy to say what happens when five or more stamens have to be replaced by two carpels.

Lastly, of the several theories thus far proposed to account for the occurrence of the abnormalities, none is capable of wide application.

Sometimes the abnormalities reappear year after year; sometimes they prove inconstant. Had we a fuller knowledge, some explanation, partial or complete, might be forthcoming; for frequently, both in their distribution in the catkin and on the branch, the changes in sex show a tendency to arrangement. At times the male is above the female; at times the reverse is the case. Rarely there are three or four belts of flowers on one catkin, male succeeding female, and female male, in definite order.

4. *Apogeotropic Roots of* Bowenia spectabilis (*Hk. f.*), *By* H. H. W. PEARSON, *B.A., Cambridge.*

Apogeotropic roots arise from the upper part of the main root of *Bowenia spectabilis,* and appear just above the surface of the soil. These roots are very numerous on the old plants. Each root develops endogenously and branches above in an exogenous manner. The internal structure of the root is, in the main, the same as that of an ordinary lateral root. The external layer is composed of radially elongated cells, with their free ends not in contact, thus giving to the root a villous appearance, which can be detected by the naked eye. This 'piliferous' layer soon becomes cut off by a layer of cork.

Colonies of algæ are found inhabiting a ring of intercellular spaces in the mid-cortex. The alga is confined to a very definite zone. The portion of the cortex in which it appears is in no way specialised, the cells which are crushed by its growth being of the same size and form as those of the remainder of the cortex.

TUESDAY, SEPTEMBER 13.

The following Papers were read:—

1. *Preliminary Note on Changes in the Gland Cells of* Drosera *produced by Various Food Materials. By* LILY H. HUIE.

(Communicated by GUSTAV MANN).

The work is an extension of that previously undertaken by the authoress, an account of which has already appeared in 'Quart. Micro. Journ.,' vol. xxxix.

In the experiments now described leaves were fed with Egg-albumin, Globulin, Peptone, Fibrin, Milk, Nuclein, Nucleic acid, and Calcium phosphate, the histological changes in the gland cells being noted in each case.

The results to be described were obtained with fixing fluids, widely differing in their chemical constitution.

Egg-albumin: The basophil cytoplasm becomes pink, and is reduced in twenty to thirty hours to a mere vestige. After two days it commences to recuperate, and ultimately becomes again basophil. The changes in the nucleus comprise—(1) those of the nuclear chromosomes, (2) those of the nuclear plasm, and (3) those of the nucleoli. In the resting cell the nuclear chromatin is scanty, but immediately after feeding it commences to increase, till in twenty to thirty hours large segments are formed as in mitosis. During recuperation the segments again diminish. The eosinophil nucleoli are large in the resting cell; they diminish after feeding in direct proportion to the increase of the basophil chromatin, and finally enlarge when the chromatin segments diminish.

Peptone is absorbed much more rapidly than egg-albumin, and produces in one hour changes similar to those effected by egg-albumin in twenty to thirty hours.

Globulin also produces changes in twenty-four hours, but to a less marked degree than egg-albumin. Food passes into the tentacle between the lateral walls of the cells, and secretory products pass through the apical walls, thus producing an appearance of striæ in the food which is in contact with the tentacles.

Fibrin is digested slowly, and changes similar to but generally less pronounced than in egg-albumin are seen.

Milk is absorbed rapidly and completely. The morphological changes are less marked than with any of the above-mentioned foods. The cell plasm remains basophil throughout.

Nuclein produces almost no effect; the tentacles do not bend in, and do not secrete more copiously than before. No cytological changes are produced except very slight vacuolation of the cell plasm. All the colour reactions are the same as those of controls.

Nucleic acid produced rapid bending in of the tentacles, and extremely copious secretion. The leaves reopen in one to three days, and although the quantity of nucleic acid given is not perceptibly diminished, there are great histological changes, consisting in an almost complete disappearance of the cytoplasm (which remains basophil throughout), and of the nucleoplasm. The basophil chromatin segments remain unaltered.

Calcium phosphate produces appearances very similar to those after feeding with egg-albumin, but the cytoplasm remains basophil.

Control leaves, after the application of all the above substances, reopened in a perfectly healthy condition, as determined by their naked-eye appearances while living, and their microscopic structure after fixing by different methods.

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2. *Theoretical Calculation of an Osmotic Optimum.*

By Professor Dr. L. Errera (Brussels).

Recent researches made by Dr. F. Van Rysselberghe in the Botanical Institute of Brussels have shown that vegetable cells generally answer an *osmotic stimulus* by an appropriate *osmotic reaction*, and that the relation between stimulus and reaction follows, within wide limits, the 'law of Weber.' Hence results the possibility of predicting the existence and value of an *osmotic optimum.*

Let n be the normal osmotic pressure in a given cell;
x the osmotic pressure of an external solution applied as stimulus;
R the reaction, *i.e.* the change in the osmotic pressure of the cell in response to this stimulus. Then one has, according to Weber's law:

$$R = c \log \frac{x}{s} \text{ (}c\text{ and }s\text{ being constants).}$$

The total value of the osmotic pressure in the cell is of course $R+n$, and its excess over the pressure of the surrounding solution is,

$$y = R + n - x,$$

$$\text{or } y = c \log \frac{x}{s} + n - x.$$

It is easy to find by differentiation that this excess has a maximum value when $x = c \log e$ (e being the basis of the Naperian logarithms $= 2{,}7182818 \ldots$).

Experiments made with *Tradescantia, Symphoricarpus, Allium, Elodea, Spirogyra,* agree most satisfactorily with these theoretical results.

Additional interest arises from the fact that these values of x really correspond to *optimal* solutions, in which the cells live longer than in any other.

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3. *On the Unit to be adopted for Osmotic Measurements.*
By Professor Dr. L. ERRERA.

The investigations alluded to in the preceding note have proved that de Vries' constant *isotonic coefficients*, excellent as they are for a first approximation, are not sufficiently exact for more minute experiments. Here it is advisable to use, instead of them, the coefficients of electric conductivity, which vary slightly with the concentration of the solution.

Thus, osmotic pressures are not strictly proportional to the concentration of the plasmolysing solutions, and these pressures ought no more to be expressed in molecule-grams of KNO_3, as is now generally done. The use of *an atmosphere* as unit, though better, is also objectionable, as it varies from one place to another.

I would therefore suggest to adopt the C.G.S. unit of pressure, viz. 1 dyne per sq. cm., or rather (to avoid useless decimals) 1 *myriadyne per sq. cm., i.e.* the pressure of 10,000 dynes per sq. cm., the dyne being the force which gives the mass of 1 gram in 1 second an acceleration of 1 cm. per second.

This unit is roughly equal to $\frac{1}{100}$ atmosphere; it is found to be very convenient for all sorts of osmotic calculations.

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4. *The Knight-Darwin Law. By* FRANCIS DARWIN, *F.R.S.*

The Knight-Darwin law in its briefest form is a positive statement that no plant self-fertilises itself for perpetuity. It was shown that in this form it cannot be found in Knight, and that Darwin adopted the more general statement that Nature abhors perpetual self-fertilisation. Modern writers are inclined to condense Darwin's contribution to Floral Biology to serve such aphorism, or, rather, to accept such aphorism, as a condensation of his contributions, and when exceptions to it occur, or when it does not explain everything, to attempt to construct new foundations for their science. It was shown that the foundations on which it rests are not in need of such an underpinning process, and Darwin's generalisations still suffice. The true interest of the Knight-Darwin law is in relation to wider questions of sex, and not simply as a basis for the study of floral mechanism.

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5. *Structure of the Yeast-cell. By* Professor Dr. L. ERRERA.

A study of the cells of *Saccharomyces Cerevisiæ* has led me to the following conclusions, part of which merely confirm former researches: 1. A relatively large nuclear body exists in each adult cell. 2. Young cells contain no such body; a little later the old nuclear body divides, and one of its two daughters wanders through the narrow connecting-channel into the young cell. 3. After the division is complete, the two cells are still kept together by a mucilaginous neck-shaped pedicel, which appears not to have been noticed hitherto. It may persist or not, thus explaining the occurrence of cell-chains or of isolated cells in different races of Yeast. 4. Carbohydrates are stored up in Yeast in the form of glycogen, which accumulates or disappears from the vacuoles very rapidly, according to conditions of nutrition and growth. The colour given by a known quantity of iodine-solution to a known amount of Yeast-culture shows these variations most sharply. The change of tint by heat after iodine-action, and the destruction of the intracellular glycogen by saliva, also give very clear results.

6. *The Structure of the Yeast Plant.* *By* HAROLD WAGER.

1. The yeast cell possesses a spherical, deeply-stained body which has been by many observers regarded as a nucleus. This body is present in all cells except young cells in process of formation.

2. In close contact with this nuclear body is a vacuole which contains granules and a network-like structure capable of staining in nuclear stains. The vacuole is often surrounded by granules which stain in the same manner.

3. These two—the nuclear body and the vacuole—are in close contact with one another, and in the process of division a portion of each passes into the daughter cell.

4. The granules of *Hieronymus* occur, under the conditions described by him, in large numbers; and such cells are always found to contain granules which are stainable in alkanin. It is very likely, therefore, that some or all of the granules described by him are of an oily nature, although they do not easily dissolve in ether.

7. *Observations on the Cytology of* Achlya Americana (*Humphrey*) var. nov.

By A. H. TROW.

1. The nucleus in *Achlya Americana* has a structure which agrees in many respects with that of the higher plants. Nuclei have been observed to undergo indirect division in the oögonia and antheridia; spirem monaster and diaster stages have been observed.

2. Most of the oögonial nuclei undergo degeneration, and the eggs even in the earliest stages of their development are uni-nucleate.

3. Fertilisation takes place as in *Saprolegnia diclina* and *S. mixta*; the fertilising tube possesses a single nucleus.

4. The fusion of the gamete nuclei is generally delayed for two or three days, but the fusion apparently always takes place a day or two before the oöspore becomes fully ripe.

5. Fertilisation has thus been proved to take place in *Saprolegnia diclina*, *S. mixta*, and in the variety of *Achlya Americana* which the author proposes to call var. *Cambrica*.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
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1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, and 2 Whitehall-court, S.W.
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1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1885. ‡*Abernethy, David W. Ferryhill Cottage, Aberdeen.*
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., C.B., D.C.L., F.R.S., F.R.A.S. Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.

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1863. *ATTFIELD, J., M.A., Ph.D., F.R.S., F.C.S. 111 Temple-chambers, E.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, W.

Year of Election.

1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 41 Kensington Park Gardens, W.

1884. ‡Baby, The Hon. G. Montreal, Canada.
1883. *Bach, Madame Henri. 12 Rue Fénélon, Lyons.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 114 Eaton-square, S.W.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. ‡Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. 7 Drummond-place, Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡*Bailey, W. H. Summerfield, Eccles Old-road, Manchester.*
1866. ‡*Baillon, Andrew. British Consulate, Brest.*
1894. *Baily, Francis Gibson, M.A. 11 Ramsay-garden, Edinburgh.
1878. ‡Baily, Walter. 4 Roslyn-hill, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1897. §BAIN, JAMES, jun. Toronto.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1898. §Baker, Herbert M. Wallcroft. Durdham Park, Clifton, Bristol.
1898. §Baker, Hiatt C. Mary-le-Port-street, Bristol.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, The Right Hon. G. W., M.P. 24 Addison-road, Kensington, W.
1894. §Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.

Year of Election.

1890. ‡Bamford, Professor Harry, B.Sc. McGill University, Montreal, Canada.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1894. §Barclay, Arthur. 29 Gloucester-road, South Kensington, S.W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, S.E.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Priddy Vicarage, Wells, Somerset.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. Deene, Tooting Bec-road, Streatham, S.W.
1889. §Barlow, H. W. L., M.A., M.B., F.C.S. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
1885. *BARLOW, WILLIAM, F.G.S. The Red House, Great Stanmore.
1873. ‡BARLOW, WILLIAM HENRY, F.R.S., M.Inst.C.E. High Combe, Old Charlton, Kent.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1881. ‡BARR, ARCHIBALD, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1895. ‡*Barr, James Mark. Central Technical College, E.C.*
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Abbotsgate, Huyton, near Liverpool.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *BARRINGTON, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.

Year of Election.
1893. *BARROW, GEORGE, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡BARRY, Right Rev. ALFRED, D.D., D.C.L. The Cloisters, Windsor.
1862. *BARRY, CHARLES. 1 Victoria-street, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, S.W.
1875. ‡BARRY, Sir JOHN WOLFE-, K.C.B., F.R.S., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, G. C. T., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1898. §Bason, Vernon Millward. 7 Princess-buildings, Clifton, Bristol.
1876. ‡Bassano, Alexander. 12 Montagu-place, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *BASSET, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, N.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E., C.M.G., Controller General, Statistical Department. Board of Trade, 7 Whitehall Gardens, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡BATESON, WILLIAM, M.A., F.R.S. St. John's College, Cambridge.
1881. *BATHER, FRANCIS ARTHUR, M.A., F.G.S. 135 Kensington High-street, W.; and British Museum (Natural History), S.W.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. 8 Royal Mint, E.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.

Year of
Election.

1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, W.
1882.§§Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. Oxford.
1889. §Beare, Prof. T. Hudson, F.R.S.E., M.Inst.C.E. University College, W.C.
1842. *Beatson, William. Ash Mount, Rotherham.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. Post Office, Knutsford, Cheshire.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, W.C.
1896. ‡Beazer, C. Hindley, near Wigan.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, S.W.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1896. §Bedford, F. P. King's College, Cambridge.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L., M.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. Howell Hill Lodge, Ewell, Surrey.
1896. §Bell, James. Care of the Liverpool Steam Tug Co., Limited, Chapel-chambers, 28 Chapel-street, Liverpool.
1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.

Year of Election.
1883. *Bell, John Henry. Dalton Lees, Kirkheaton, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1893. ‡BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc., Professor of Biology in the University of Otago, New Zealand.
1891. ‡Bennett, Alfred Rosling. 44 Manor Park-road, Harlesden, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, N.W.
1896. §Bennett, George W. West Ridge, Oxton, Cheshire.
1881. §Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Hall, East Ilsley, Berkshire.
1896. ‡Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, South Africa.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1897.§§Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §Berkeley, The Right Hon. the Earl of. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1898. §Berridge, Miss C. E. 17 Rotunda-terrace, Cheltenham.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1882. *Bessemer, Henry. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. 55 Gunterstone-road, W.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1890. §Bevington, Miss Mary E. Merle Wood, Sevenoaks, Kent.
1870. ‡Bickerton, A.W. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1898. §Billington, Charles. Wolstanton, Staffordshire.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, Sheffield.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.

Year of Election.

1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Hospital, Chorley, Lancashire.
1871. *BISCHOF, GUSTAV. 19 Ladbroke-gardens, W.
1892. ‡*Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.*
1894. ‡Bisset, James. 5 East India-avenue, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Major W. H. Engineer's Office, Cincinnati, Ohio, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. ‡*Black, William. 12 Romulus-terrace, Gateshead.*
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Kelvinside, Glasgow.
1896. §Blackie, Walter W., B.Sc. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1896. ‡Blackwood, J. M. 16 Oil-street, Liverpool.
1886. ‡Blaikie, John, F.L.S. The Bridge House, Newcastle, Staffordshire.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, W.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. 69 Comeragh-road, W.
1846. *Blake, William. Bridge, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1887. ‡Blamires, George. Cleckheaton.
1881. ‡Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. ‡Blamires, William. Oak House, Taylor Hill, Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡BLANFORD, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., B.Sc. Newnham Lea, Grange-road, Cambridge.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880. ‡Bloxam, G. W., M.A. 11 Presburg-street, Clapton, N.E.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1883. ‡Blyth, Miss Phœbe. 27 Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.

Year of Election.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1898. §Bolton, J. W. Baldwin-street, Bristol.
1894. §Bolton, John. Clifton-road, Crouch End, N.
1898. §Bonar, J., M.A., LL.D. 1 Redington-road, Hampstead, N.W.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, N.W.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, N.W.
1898. §Booby, Edward P. 2 Clifton-terrace, Torquay.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Charles, D.Sc., F.S.S. 2 Talbot-court, Gracechurch-street, E.C.
1883. §Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, S.W.
1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S. Tenerife.
1896. ‡Bose, Dr. J. C. Calcutta, India.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Otterwood, Beaconsfield-road, Weston-super-Mare.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. §§Boulnois, Henry Percy, M.Inst.C.E. 44 Campden House Court, Kensington, W.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, S.W.
1883. ‡Bourne, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. *Bourne, G. C., M.A., F.L.S. Savile House, Mansfield-road, Oxford.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.
1866. §Bourne, Stephen, F.S.S. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. §§Bovey, Henry T., M.A., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *Bower, F. O., D.Sc., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow.

Year of Election.

1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Royal Societies Club, St. James's-street, S.W.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Mayfield, Knutsford, Cheshire.
1887. §§Box, Alfred Marshall. 68 Huntingdon-road, Cambridge.
1895. *BOYCE, RUBERT, M.B., Professor of Pathology, University College, Liverpool.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S. 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1864. ‡BRAHAM, PHILIP. 3 Cobden-mansions, Stockwell-road, S.E.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1898. §Bramble, James R. Seafield, Weston-super-Mare.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. The Rectory, Dickleburgh.
1885. *Bratby, William, J.P. Alton Lodge, Hale, Bowdon, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. *Bretherton, C. E. Goldsmith-buildings, Temple, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 159 Strand, W.C.
1886. §§Bridge, T. W., M.A., D.Sc., Professor of Zoology in the Mason Science College, Birmingham.
1870. *Bridson, Joseph R. Bryerswood, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, S.W.
1893. §§Briscoe, Albert E., A.R.C.Sc., B.Sc. Battersea Polytechnic, S.W.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.

Year of Election.

1898. §BRISTOL, the Right Rev. G. F. BROWNE, Lord Bishop of, D.D. 17 The Avenue, Clifton, Bristol.
1879. *BRITTAIN, W. H., J.P., F.R.G.S. Alma Works, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1897.§§Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1859. *BRODHURST, BERNARD EDWARD, F.R.C.S. 21 Portland-place, W.
1883. *Brodie, David, M.D. Care of Mrs. Johnson, Ventnor House, Canterbury.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1881. ‡Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1887. *Bros, W. Law. Camera Club, Charing-cross-road, W.C.
1883. *Brotherton, E. A. Arthington Hall, viâ Leeds.
1883. *Brough, Mrs. Charles S. Rosendale Hall, West Dulwich, S.E.
1886. ‡Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 29 Wheeley's-road, Birmingham.
1863. *BROWN, ALEXANDER CRUM, M.D., LL.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1896. ‡Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Sir Charles Gage, M.D., K.C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1883. ‡Brown, Mrs. H. Bienz. 62 Stanley-street, Aberdeen.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §BROWN, HORACE T., LL.D., F.R.S., F.G.S. 52 Nevern-square, S.W.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.
1895. ‡BROWN, J. ALLEN, J.P., F.R.G.S., F.G.S. 7 Kent-gardens, Ealing, W.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Longhurst, Dunmurry, Belfast.
1881. **Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.*
1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.
1895. *Brown, John Charles. 7 Second-avenue, Nottingham.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. **Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.*

Year of Election.

1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1897.§§Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. §Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897.§§Brown, Richard. Jarvis-street, Toronto, Canada.
1896. ‡Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §BROWN, T. FORSTER, M.Inst.C.E., F.G.S. Guild Hall Chambers, Cardiff.
1865. ‡Brown, William. 41A New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. ‡Browne, Harold Crichton. Crindon, Dumfries.
1895. *Browne, Henry Taylor. 10 Hyde Park-terrace, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891. ‡BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1887. ‡*Brownell, T. W. 6 St. James's-square, Manchester.*
1865. ‡Browning, John, F.R.A.S. 63 Strand, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡*Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.*
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1893. ‡Bruce, William S. University Hall, Riddle's-court, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, I. 15 Devonshire-terrace, W.
1875. ‡Brunlees, John, M.Inst.C.E. 12 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡BRUNTON, T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. §Brutton, Joseph. Yeovil.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Bangor.
1884. ‡BRYCE, Rev. Professor GEORGE. Winnipeg, Canada.
1897.§§BRYCE, Right Hon. JAMES, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1894. ‡Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1865. **Buckley, Henry. 18 Princes-street, Cavendish-square, W.*
1886. §Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, W.C.

Year of Election.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §BULLEID, ARTHUR, F.S.A. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §§BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. ‡Burke, John. Owens College, Manchester.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, E.C.
1883. *Burrows, Abraham. Russell House, Rhyl, North Wales.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1897. §§Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, W.
1897. §§Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Trinity College, Cambridge.
1895. §Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, Cleveland-road, Ealing, W.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill. Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡*Buxton, Miss F. M. Newnham College, Cambridge.*
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, S.W.

Year of
Election.

1872. ‡Buxton, Sir Thomas Fowell, Bart., K.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth Park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1886. **Caldwell, William Hay. Cambridge.*
1868. ‡Caley, A. J. Norwich.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 35 Huskisson-street, Liverpool.
1897. §CALLENDAR, Professor HUGH L., M.A., F.R.S. University College, Gower-street, W.C.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Sir Charles, Bart., M.D., LL.D. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, Right Hon. James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1897.§§Campbell, Major J. C. L. New Club, Edinburgh.
1898. §Campbell, Mrs. Napier. 81 Ashley-gardens, S.W.
1897.§§Campion, B. W. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1897. §Cannon, Herbert. Erith, Kent.
1898. CANTERBURY, Right Hon. and Most Rev. F. TEMPLE, Lord Archbishop of, Lambeth Palace, S.E.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1894. §Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1880. ‡Capper, Robert. 18 Parliament-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 18 Parliament-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, W.
1896. *Carden, H. V. Lagonda, Lancaster-road, Wimbledon.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1898. §Carlile, George M. 7 Upper Belgrave-road, Bristol.
1867. ‡Carmichael, David (Engineer). Dundee.
1897. §Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.

Year of Election.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897.§§Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal-avenue, Belfast.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1897. §Carter, E. Tremlett. Broadclyst, 53 Cloudesdale-road, S.W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡*Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.*
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1896. §Cartwright, Miss Edith G. 7 Fairfax-road, N.W.
1878. *Cartwright, Ernest H., M.A., M.D. 1 Courtfield-gardens, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I., Borough and Water Engineer. Albion-place, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1897.§§Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
1888. ‡*Cater, R. B. Avondale, Henrietta Park, Bath.*
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Lancaster House, Palace-road, Tulse-hill, S.W.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, Assoc.M.Inst.C.E. Colába Observatory, Bombay.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Abchurch-chambers, E.C.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 1 Grand-avenue, Brighton.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.

Year of Election.

1897.§§Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡*Charnock, Richard Stephen, Ph.D., F.S.A. Crichton Club, Adelphi-terrace, W.C.*
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, S.W.
1886. *Chattock, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡Chauveau, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 19 Portman-street, Portman-square, W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1896. ‡Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Colonel Sir H. C., R.E., K.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1896. ‡Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. 26 Dornton-road, Balham, S.W.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *Chree, Charles, D.Sc., F.R.S., Superintendent of the Kew Observatory, Richmond, Surrey.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Graveney, S.W.
1876. *Chrystal, George, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §Church, A. H., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §Church, Colonel G. Earl, F.R.G.S. 216 Cromwell-road, S.W.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, E.C.
1896. §Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1890. ‡Clark, E. K. 13 Wellclose-place, Leeds.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892.§§Clark, James, M.A., Ph.D., Professor of Agriculture in the Yorkshire College, Leeds.
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc. 112 Wool Exchange, Edinburgh.

Year of Election.

1861. ‡CLARK, LATIMER, F.R.S., F.R.A.S., M.Inst.C.E. 11 Victoria-street, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard, J.P. Fairlawn, 157 Peckham-rye, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. ‡Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1897. §Clarke, Colonel S. C., R.E. Parklands, Caversham, near Reading.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1896. §Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889.§§CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1898. §Clissold, H. 30 College-road, Clifton, Bristol.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 38 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S. London County Council, Spring-gardens, S.W.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
1897.§§Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Westfield, Ilkley, Yorkshire.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. §Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, S.W.
1896. *Coghill, Percy de G. Camster, Cressington.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1894. *Colby, Miss E. L., B.A. Carregwen, Aberystwyth.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carregwen, Aberystwyth.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1893. ‡Cole, Grenville A. J., F.G.S. Royal College of Science, Dublin.

Year of Election.

1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1894. ‡Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, S.W.
1897. §Coleman, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. ‡Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 16 Campden-grove, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. ‡Collinge, Walter E. Mason College, Birmingham.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 69 Great Russell-street, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. 162 Barry-road, S.E.
1892. ‡Colman, H. G. Mason College, Birmingham.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. §§Colquhoun, A. H. U., B.A. 39 Borden-street, Toronto, Canada.
1896. *Comber, Thomas, F.L.S. Leighton, Parkgate, Chester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡COMMON, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1892. ‡Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1896. ‡Connacher, W. S. Birkenhead Institute, Birkenhead.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1881. ‡CONROY, Sir JOHN, Bart., M.A., F.R.S. Balliol College, Oxford.
1893. ‡Conway, Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, W.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1895. ‡Cooke, Miss Janette E. Holmwood, Thorpe, Norwich.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1896. ‡Cookson, E. H. Kiln Hey, West Derby.
1888. ‡*Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.*
1895. ‡Cooper, Charles Friend, M.I.E.E. 68 Victoria-street, Westminster, S.W.
1893. ‡Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡Cooper, George B. 67 Great Russell-street, W.C.

Year of Election.
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡COPELAND, RALPH, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1885. ‡*Copland, W., M.A. Tortorston, Peterhead, N.B.*
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1891. §§Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 9 Alwyne-square, N.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1881. §Cordeaux, John. Great Cotes House, R.S.O., Lincoln.
1883. *Core, Professor Thomas H., M.A. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College, London. 19 Savile-row, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan, M.Sc., F.R.G.S. Branksome Cliff, Branksome Park, Bournemouth.
1884. *Cornwallis, F. S. W., M.P., F.L S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, W.C.
1891. **Cotsworth, Haldane Gwilt. G. W.R. Laboratory, Swindon, Wilts.*
1874. *COTTERILL, J. H., M.A., F.R.S. Broadwater, Tweedy-road, Bromley.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, S.W.
1896. ‡COURTNEY, Right Hon. LEONARD, M.P. 15 Cheyne Walk, Chelsea, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. ‡Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 17 King William-street, Strand, W C.
1895. *COWELL, PHILIP H. Royal Observatory, Greenwich, S.E.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. ‡Crabtree, William. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.

Year of
Election.

1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §CRAIGIE, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. ‡Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Craiglockhart, Edinburgh.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §CREAK, Captain E. W., R.N., F.R.S. 9 Hervey-road, Blackheath, S.E.
1896.§§Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crewe, W. Outram. Central Buildings, North John-street, Liverpool.
1896. §Crichton, H. 6 Rockfield-road, Anfield, Liverpool.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡*Crombie, Charles W. 41 Carden-place, Aberdeen.*
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.
1898. §Crooke, William. West Leigh, Arterberry-road, Wimbledon.
1865. §CROOKES, Sir W., F.R.S., V.P.C.S. (PRESIDENT.) 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *Crookshank, E. M., M.B., Professor of Bacteriology in King's College, London, W.C.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887. §Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A., F.G.S. Halecote, Grange-over-Sands.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1894. ‡Crow, C. F. Home Lea, Woodstock-road, Oxford.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.

Year of Election.

1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *CULVERWELL, EDWARD P., M.A. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1897. §§Cumberland, Barlow. Toronto, Canada.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1898. §Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. WILLIAM, D.D., D.Sc. Trinity College, Cambridge.
1892. §Cunningham-Craig, E. H., B.A., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1892. *Currie, James, jun., M.A. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1898. §Curtis, John. 1 Christchurch-road, Clifton, Bristol.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, S.W.

1889. ‡Dagger, John H., F.I.C. Victoria Villa, Lorne-street, Fairfield, Liverpool.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1898. §Dalby, W. E. 6 Coleridge-road, Crouch End, N.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1894. ‡Dalgleish, W. Scott, M.A., LL.D. 25 Mayfield-terrace, Edinburgh.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1896. §§Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.

Year of Election.

1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, W.
1897. §Darbishire, C. W. Elm Lodge, Elm-row, Hampstead, N.W.
1897. §Darbishire, F. V. Rossplatz 12ɪ, Leipzig.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. 26 George-street, Manchester.
1896.§§Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1894. §DARWIN, Major LEONARD, Sec. R.G.S. 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 11 St. James's-square, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1898. §Davey, William John. 6 Water-street, Liverpool.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887. ‡Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1893. *Davies, Rev. T. Witton, B.A., Ph.D. Midland Baptist College, Nottingham.
1898. §Davies, Wm. Howell, J.P. Down House, Stoke Bishop, Bristol.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 13 St. Ermin's-mansions, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. 18 Clare-road, Halifax, Yorkshire.
1885. *Davis, Rev. Rudolf. 1 Victoria-avenue, Evesham.
1891. ‡*Davis, W.* 48 *Richmond-road, Cardiff.*
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 16 Manor-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, E. W., M.D. Kimmage Lodge, Roundtown, Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1897.§§DAWSON, G. M., C.M.G., LL.D., F.R.S., Director of the Geological Survey of Canada. Ottawa, Canada.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.

Year of Election.

1855. §DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S. 293 University-street, Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, T. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, S.W.
1861. ‡*Deacon, Henry. Appleton House, near Warrington.*
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. §Deeley, R. M. 38 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1870. ‡De Meschin, Thomas, B.A., LL.D. 2 Dr. Johnson's Buildings, Temple, E.C.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1897.§§Denison, F. Napier. The Observatory, Toronto, Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889.§§DENNY, ALFRED, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, W.
1874.§§DE RANCE, CHARLES E., F.G.S. 55 Stoke-road, Shelton, Stoke-upon-Trent.
1896. ‡DERBY, The Right Hon. the Earl of, G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1868. ‡DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., Pres.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, W.
1887. ‡DE WINTON, Major-General Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Trinity College, Cambridge.
1896. ‡D'Hemry, P. 136 Prince's-road, Liverpool.
1897.§§Dick, D. B. Toronto, Canada.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund, M.A., F.G.S. 2 Starkie-street, Preston.
1887. §Dickson, H. N., F.R.S.E., F.R.G.S. 2 St. Margaret's-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.

Year of Election.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1898. *Dix, John William S. Hampton Lodge, Durdham Park, Clifton, Bristol.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, S.W.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1896. §Dixon-Nuttall, F. R. Ingleholme, Ecclestone Park, Prescot.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne-park, W.
1897.§§Doberck, William. The Observatory, Hong Kong.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1893. ‡Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1894. ‡*Dockar-Drysdale, Mrs. 39 Belsize-park, N.W.*
1875. *Docwra, George. 2 Paulton-square, Chelsea, S.W.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897.§§Dodge, Richard E. Teachers' College, Morningside Heights, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1898. §Dole, James. Redland House, Bristol.
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, M.Inst.C.E. The Mount, Wray Park, Reigate.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. South Kensington Museum, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. **Doughty, Charles Montagu. Henwick, Newbury.*
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡*Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.*
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1894. ‡*Dowie, Robert Chambers.* 13 *Carter-street, Higher Broughton, Manchester.*
1884. *Dowling, D. J. Bromley, Kent.
1857. ‡*Downing, S., LL.D.* 4 *The Hill, Monkstown, Co. Dublin.*
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 39 Old Queen-street, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. ‡Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.

Year of Election.

1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, W.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. 11 Chelsea-embankment, S.W.
1852. ‡DUFFERIN AND AVA, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, S.W.
1866. *Duncan, James. 9 Mincing-lane, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡*Duncan, William S.* 143 *Queen's-road, Bayswater, W.*
1896. ‡Duncanson, Thomas. 16 Deane-road, Liverpool.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 7 Spencer-road, Grove Park, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1896. *Dunkerley, S., M.Sc. Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. Northern Polytechnic Institute, Holloway-road, N.
1883. ‡Dunn, Mrs. Northern Polytechnic Institute, Holloway-road, N.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §§Dunnington, F. P. University Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R. Newcastle-circus, Nottingham.
1891. ‡Dunstan, Mrs. Newcastle-circus, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1898. §Durrant, R. G. Marlborough College, Wilts.
1895. *Dwerryhouse, Arthur R. 65 Louis-street, Leeds.
1887. ‡Dyason, John Sanford. Cuthbert-street, W.

Year of Election.

1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.
1895.§§Dymond, Thos. S., F.C.S. County Technical Laboratory, Chelmsford.
1897.§§Dynan, Miss. 75 Queen's-park, Toronto, Canada.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. ‡Earle, Hardman A. 29 Queen Anne's-gate, Westminster, S.W.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. §Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, E.C.
1867. *Edward, Allan. Farington Hall, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1896. §Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890.§§Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 113 Cannon-street, E.C.
1885. ‡*Ellingham, Frank. Thorpe St. Andrew, Norwich.*
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡Elliott, Thomas Henry, C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1898. §Elliott, W. J. 14 Buckingham-place, Clifton, Bristol.
1877. ‡*Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.*
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY. Woodhaye, Ivy Bridge, Devon.
1891. §Ellis, Miss M. A. 11 Canterbury-road, Oxford.

Year of
Election.

1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, W.C.
1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
1883. ‡Elwes, Captain George Robert. Bossington, Bournemouth.
1887. §ELWORTHY, FREDERICK T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1897.§§Ely, Robert E. Cambridge, Massachusetts, U.S.A.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley, D.C.L. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1890. ‡*Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.*
1894. ‡Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894.§§Erskine-Murray, James. 46 Great King-street, Edinburgh.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins Hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Hayesleigh, Montague-road, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 20 Albert-square, Manchester.
1869. ‡ETHERIDGE, R., F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, S.W.
1883. ‡Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *Evans, A. H. Care of R. H. Porter, 18 Prince's-street, W.
1887. *Evans, Mrs. Alfred W. A. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1870. *EVANS, ARTHUR JOHN, M.A., F.S.A. Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. 41 Lancaster-gate, W.
1896.§§Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡*Evans, Horace L. 6 Albert-buildings, Weston-super-Mare.*
1883. *Evans, James C. 175 Lord-street, Southport.
1883. *Evans, Mrs. James C. 175 Lord-street, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1898. §Evans, Jonathan L. 4 Litfield-place, Clifton, Bristol.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1881. ‡Evans, Lewis. Llanfyrnach, R.S.O., Pembrokeshire.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.

Year of Election.

1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E. Derryvolgie-avenue, Belfast.
1895. §Everett, W. H., B.A. University College, Nottingham.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., B.Sc., F.R.S., F.R.S.E., M.Inst. C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Langdale Lodge, Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. §Fairbrother, Thomas. 46 Lethbridge-road, Southport.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡*Fairley, William. Beau Desert, Rugeley, Staffordshire.*
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Liverpool.
1883. ‡Fallon, Rev. W. S. 9 St. James's-square, Cheltenham.
1898. §Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1877. §FARADAY, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡Fards, G. Penarth.
1892. *FARMER, J. BRETLAND, M.A., F.L.S., Professor of Botany, Royal College of Science, Exhibition-road, London. 4 Lichfield-road, Kew.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1897. *Farnworth, Mrs. Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡Farquharson, Colonel J., R.E. Ordnance Survey Office, Southampton.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, The Very Rev. FREDERIC WILLIAM, D.D., F.R.S. The Deanery, Canterbury.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡*Farrelly, Rev. Thomas. Royal College, Maynooth.*
1897. §§Farthing, Rev. J. C., M.A. The Rectory, Woodstock, Ontario, Canada.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1886. §Felkin, Robert W., M.D., F.R.G.S. 6 Crouch Hall-road, N.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.

Year of Election.

1883. ‡Fenwick, E. H. 29 Harley-street, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1896. *Ferguson, John. Colombo, Ceylon.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1883. ‡Fernald, H. P. Clarence House, Promenade, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡FERRIER, DAVID, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1897. §§Ferrier, W. F. Geological Survey, Ottawa, Canada.
1897. §§Fessenden, Reginald A. Western University of Pennsylvania, Alleghany, Pennsylvania, U.S.A.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1897. §§Field, George Wilton. Experimental Station, Kingston, Rhode Island, U.S.A.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *FIELD, ROGERS, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1892. ‡Findlay, J. R., B.A. 3 Rothesay-terrace, Edinburgh.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 88 Upper Hanover-street, Sheffield.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 25 Blenheim-gardens, Willesden Green, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., M.P., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, Sir J. G., M.A., LL.D. Athenæum Club, S.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., D.Sc., F.R.S., Professor of Natural and Experimental Philosophy in Trinity College, Dublin.
1885. *FitzGerald, Professor Maurice, B.A. 32 Eglantine-avenue, Belfast.
1894. §§Fitzmaurice, M., M.Inst.C.E. Nile Reservoir, Assuan, Egypt.

Year of Election.

1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.

1888. *FITZPATRICK, Rev. THOMAS C. Christ's College, Cambridge.

1897.§§Flavelle, J. W. 565 Jarvis-street, Toronto, Canada.

1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.

1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, Glasgow.

1876. ‡Fleming, Sir Sandford, K.C.M.G., F.G.S. Ottawa, Canada.

1867.§§FLETCHER, ALFRED E., F.C.S. Delmore, Caterham, Surrey.

1870. ‡Fletcher, B. Edgington. Norwich.

1890. ‡Fletcher, B. Morley. 7 Victoria-street, S.W.

1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.

1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 36 Woodville-road, Ealing, W.

1862. §FLOWER, Sir WILLIAM HENRY, K.C.B., LL.D., D.C.L., D.Sc., F.R.S., F.L.S., F.G.S., F.R.C.S. 26 Stanhope-gardens, S.W.

1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.

1877. *Floyer, Ernest A. Downton, Salisbury.

1890. *Flux, A. W., M.A., Professor of Political Economy in the Owens College, Manchester.

1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.

1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.

1891.§§Foldvary, William. Museum Ring, 10, Buda Pesth.

1879. ‡*Foote, Charles Newth, M.D.* *3 Albion-place, Sunderland.*

1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, E.C.

1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.

1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.

1897.§§Forbes, J., Q.C. Hazeldean, Putney-hill, S.W.

1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.

1890. ‡FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.

1875. *FORDHAM, H. GEORGE. Odsey, Ashwell, Baldock, Herts.

1894. ‡Forrest, Frederick. Beechwood, Castle Hill, Hastings.

1887. ‡FORREST, The Right Hon. Sir JOHN, K.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.

1883. ‡FORSYTH, A. R., M.A., D.Sc., F.R.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.

1884. ‡Fort, George H. Lakefield, Ontario, Canada.

1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.

1882. ‡*Forward, Henry.* 10 *Marine-avenue, Southend.*

1896. ‡FORWOOD, Sir WILLIAM B., J.P. Ramleh, Blundellsands, Liverpool.

1875. ‡Foster, A. Le Neve. 51 Cadogan-square, S.W.

1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.

1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.

1883. ‡Foster, Mrs. C. Le Neve. Llandudno.

1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S. (GENERAL TREASURER.) 18 Daleham-gardens, Hampstead, N.W.

1896. ‡Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.

1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.

1859. *FOSTER, MICHAEL, M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S., Professor of Physiology in the University of Cambridge. (PRESIDENT-ELECT.) Great Shelford, Cambridge.

Year of Election.

1863. ‡Foster, Robert. The Quarries, Grainger Park-road, Newcastle-upon-Tyne.
1896. ‡Fowkes, F. Hawkshead, Ambleside.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.
1882. ‡FOWLER, Sir JOHN, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1883. *Fox, Charles. The Chestnuts, Warlingham, Surrey.
1883. §FOX, Sir CHARLES DOUGLAS, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.
1896. ‡Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1888. ‡Fox, Thomas. Court, Wellington, Somerset.
1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1845. ‡FRANKLAND, Sir EDWARD, K.C.B., M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry and Metallurgy in the Mason College, Birmingham.
1894. §Franklin, Mrs. E. L. 50 Porchester-terrace, W.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1897. §§Fraser, Sir Malcolm, K.C.M.G. 15 Victoria-street, S.W.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. Rowmore House, Garelochhead, N.B.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. 12 Buckingham Palace-gardens, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., F.R.G.S. 1 Airlie-gardens, Campden Hill, W.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Cavaliere. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. Chesterfield, Meads, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1898. §FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1898. §Fry, Francis J. Leigh Woods, Clifton, Bristol.
1898. §Fry, J. Storrs. Union-street, Bristol.
1875. *Fry, Joseph Storrs. 13 Upper Belgrave-road, Clifton, Bristol.

Year of
Election.

1898. §Fryer, Alfred C. 13 Eaton-crescent, Clifton, Bristol.
1884.§§Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1895. ‡Fullarton, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. 71 Lexham-gardens, Kensington, W.
1884.§§Fuller, William, M.B. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡*Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.*
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1896. ‡Gair, H. W. 21 Water-street, Liverpool.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡GAIRDNER, Sir W. T., K.C.B., M.D., LL.D., F.R.S., Professor of Medicine in the University of Glasgow. The University, Glasgow.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J., M.P. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *GALTON, Sir DOUGLAS, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. 12 Chester-street, Grosvenor-place, S.W.
1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. New University Club, St. James's-street, S.W.
1870. §Gamble, Lieut.-Colonel Sir D., Bart., C.B. St. Helens, Lancashire.
1889.§§Gamble, David, jun. Ratonagh, Colwyn Bay.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, M.A., F.L.S. Arundel House, Stoke-road, Guildford.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. 8 Avenue de la Gare, Lausanne, Switzerland.
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1898. §Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1887. ‡GARDINER, WALTER, M.A., F.R.S. 45 Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1894. ‡Gardner, J. Addyman. 5 Bath-place, Oxford.
1896.§§Gardner, James. The Groves, Grassendale, Liverpool.
1882. ‡GARDNER, JOHN STARKIE. 29 Albert Embankment, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. ‡GARSON, J. G., M.D. 64 Harley-street, London, W.
1894. *Garstang, Walter, M.A., F.Z.S. Marine Biological Laboratory, Plymouth.

Year of Election.

1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Braganstown, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Devanha House, Bowes-road, New Southgate, N.
1889. ‡Garwood, E. J., B.A., F.G.S. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. The Uplands, Great Shelford, near Cambridge.
1896. §Gatehouse, Charles. Westwood, Noctorum, Birkenhead.
1862. *Gatty, Charles Henry, M.A., LL.D., F.R.S.E., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.
1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. ‡Geddes, Professor Patrick. Ramsay-garden, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. 10 Chester-terrace, Regent's-park, N.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 31 Merchiston-avenue, Edinburgh.
1898. §Gemmill, James F., M.A., M.B. 16 Dargavel-avenue, Dumbreck, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1892. ‡Gibson, Francis Maitland. Care of Professor Gibson, 20 George-square, Edinburgh.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1896. ‡Gibson, Harvey, M.A., Professor of Botany, University College, Liverpool.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. ‡GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. Athenæum Club, S.W.
1888. *_Gifford, H. J. Lyston Court, Tram Inn, Hereford._
1898. *Gifford, J. William. Chard.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, Sir JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1883. §§Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡Gilchrist, J. D. F. Carvenon Anstruther, Scotland.

Year of Election.

1896. *GILCHRIST, PERCY C., F.R.S., M.Inst. C.E. Frognal Bank, Finchley-road, Hampstead, N.W.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, DAVID, C.B., LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1888. §Gill, John Frederick. Douglas, Isle of Man.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1896. ‡Gilmour, H. B. Underlea, Aigburth, Liverpool.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley. Winnipeg, Manitoba, Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., F.C.S. 17 Pembridge-square, W.
1883. *Gladstone, Miss. 17 Pembridge-square, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1897. §§Glashan, J. C. Ottawa, Canada.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S., Principal of University College, Liverpool.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
1874. ‡Glover, George T. Corby, Hoylake.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. ‡Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. 3 Clarence-terrace, Regent's Park, N.W.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1898. §Goldney, F. B. Goodnestone-park, Dover.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1890. *GONNER, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.

Year of Election.

1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. 1038 Rookery Building, Chicago, Illinois, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. 8 St. Mary-street, St. Andrews, N.B.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡Gordon, William John. 3 Lavender-gardens, S.W.
1865. ‡GORE, GEORGE, LL.D., F.R.S. 20 Easy-row, Birmingham.
1875. *GOTCH, FRANCIS, M.A., B.Sc., F.R.S., Professor of Physiology in the University of Oxford, The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill Gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill Gardens, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1892. ‡Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. §§Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. ‡Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. ‡GRAY, Professor ANDREW, M.A., LL.D., F.R.S., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1870. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. *Gray, James Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.
1892. §Gray, John, B.Sc. 351 Coldharbour-lane, Brixton, S.W.
1887. ‡Gray, Joseph W., F.G.S. Cleveland Villa, Shurdington Road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.

Year of
Election.

1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, N.W.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1888. §GREEN, J. REYNOLDS, M.A., B.Sc., F.R.S., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. Arncliffe, Grange-road, Cambridge.
1887. ‡*Greene, Friese. 162 Sloane-street, S.W.*
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, W.C.
1881. ‡Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, N.W.
1898. *Greenly, Edward. Achnashean, near Bangor, North Wales.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Driffield, near Derby.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡Greenwood, F., M.B. Brampton, Chesterfield.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1887. ‡Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1894. ‡Gregory, J. Walter, D.Sc., F.G.S. British Museum, Cromwell-road, S.W.
1896. §Gregory, R. A. 4 Cumnor-place, Sutton, Surrey.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. Care of W. L. Buchanan, Esq., 212 St. Vincent-street, Glasgow.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T. College-road, Harrow, Middlesex.
1894. *Griffith, Miss F. H. College-road, Harrow, Middlesex.
1859. *GRIFFITH, G. (ASSISTANT GENERAL SECRETARY.) College-road, Harrow, Middlesex.
1884. ‡GRIFFITHS, E. H., M.A., F.R.S. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1870. ‡Grimsdale, T. F., M.D. Hoylake, Liverpool.
1888. *Grimshaw, James Walter, M.Inst.C.E. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1894. ‡Groom, P., M.A., F.L.S. 38 Regent-street, Oxford.
1894. ‡Groom, T. T. The Poplars, Hereford.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1892. ‡Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *GROVES, THOMAS B. 9 Commercial-road, Weymouth.

Year of Election.

1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1897.§§Grünbaum, A. S., M.A., M.D. 45 Ladbroke-grove, W.
1897. §Grünbaum, O. F. F., B.A., D.Sc. Trinity College, Cambridge.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, Sir John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Pres.L.S., F.Z.S. 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1876. ‡*Guthrie, Francis. Cape Town, Cape of Good Hope.*
1883. ‡Guthrie, Malcolm. Prince's-road, Liverpool.
1896. ‡Guthrie, Tom, B.Sc. Yorkshire College, Leeds.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡GWYTHER, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, M.A., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria Park, Manchester.
1888. *Hadfield, R. A., M.Inst.C.E. The Grove, Endcliffe Vale-road, Sheffield.
1892. ‡Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rock Ferry, Cheshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1883. ‡HALIBURTON, R. G., Q.C. 13 Pall Mall, S.W.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Cowley House, Headington Hill, Oxford.
1898. §Hall, J. P. The 'Tribune,' New York, U.S.A.
1887. ‡*Hall, John. Springbank, Leftwich, Northwich.*
1885. §Hall, Samuel, F.I.C., F.C.S. 19 Aberdeen-park, Highbury, N.
1896. §Hall, Thomas B. Larch Wood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *HALL, TOWNSHEND M., F.G.S. Orchard House, Pilton, Barnstaple.
1896. ‡Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, W.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S., Professor of Physiology in King's College, London. 9 Ridgmount-gardens, Gower-street, W.C.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Fairley, Weston, Bath.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 41 Queen's-road, Aberdeen.
1881. *Hammond, Robert. Ormond House, Great Trinity-lane, E.C.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. §Hance, Edward M., LL.B. Municipal Offices, Liverpool.

Year of Election.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, S.W.
1897. §HANCOCK, HARRIS. University of Chicago, U.S.A.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. ‡Hannaford, E. P., M.Inst.C.E. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, S.W.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1892. *Harden, Arthur, Ph.D., M.Sc. 20 Kensington-crescent, W.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡*Harding, Joseph. Millbrook House, Exeter.*
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1894. ‡Hardman, S. C. 225 Lord-street, Southport.
1897. §§HARDY, Hon. ARTHUR S., Premier of the Province of Ontario. Toronto, Canada.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, W.
1898. §Harford, W. H. Oldown House, Almondsbury.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1896. ‡Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. 1 St. Mary's-road, Canonbury, N.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 1 Belmont, Tenby.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., B.Sc., F.R.S. King's College, Cambridge.
1882. ‡*Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.*
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.

Year of Election.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1898. §Harrison, A. J., M.D. Failand Lodge, Guthrie-road, Clifton, Bristol.
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡*Harrison, George. Barnsley, Yorkshire.*
1858. *HARRISON, J. PARK, M.A. 22 Connaught-street, Hyde Park, W.
1892. ‡HARRISON, JOHN. Rockville, Napier-road, Edinburgh.
1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.
1870. ‡HARRISON, REGINALD, F.R.C.S. 6 Lower Berkeley-street, Portman-square, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsay, Isle of Man.
1895. ‡Harrison, Thomas. 48 High-street, Ipswich.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *HARTLAND, E. SIDNEY, F.S.A. Highgarth, Gloucester.
1897.§§Hartley, E. G. S. Wheaton Astley Hall, Stafford.
1871. ‡HARTLEY, WALTER NOEL, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. ‡Hartley, W. P., J.P. Aintree, Liverpool.
1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., B.Sc. Owens College, Manchester.
1897. §Harvey, Arthur. Rosedale, Toronto, Canada.
1898. §Harvey, Eddie. 10 The Paragon, Clifton, Bristol.
1885.§§Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1875. *HASTINGS, G. W. 23 Kensington-square, W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
1898. §Hawkins, Major H. 1 Wells-road Villas, Glastonbury.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 2 Down-street, W., and 33 Great George-street, S.W.
1897. §Hawksley, Charles. 60 Porchester-terrace, W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E., Professor of Physiology, University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896.§§Hayes, Rev. F. C. The Rectory, Raheny, Dublin.
1896.§§Hayes, William. Fernyhurst, Rathgar, Dublin.

Year of Election.

1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1898. §Hayman, C. A. Kingston Villa, Richmond Hill, Clifton, Bristol.
1858. *HAYWARD, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rock Ferry.
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. 47 Victoria-street, Westminster, S.W.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Oak Hill, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, Manchester.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡*Heape, Joseph R. 96 Tweedale-street, Rochdale.*
1882. *Heape, Walter, M.A. Heyroun, Chaucer-road, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1898. *Heath, Arthur J. Monkton Combe School, near Bath.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1898. §Heath, R. S., M.A., D.Sc. Mason University College, Birmingham.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *HEATON, WILLIAM H., M.A., Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, S.E.
1888. *Heawood, Percy Y., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. Wootton Lodge, 39 Streatham-hill, S.W.
1881. *HELE-SHAW, H. S., LL.D., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 27 Ullett-road, Liverpool.
1897. §§Hely-Hutchinson, John. Seafield, Donahate, Dublin.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1897. §Hemming, G. W., Q.C. 2 Earl's Court-square, S.W.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Henderson, Mrs. A. L. Westmoor Hall, Brimsdown, Middlesex.
1891. *HENDERSON, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. ‡Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, Kensington, S.W.
1896. ‡Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.
1892. §§Henigan, Richard. Alma-road, The Avenue, Southampton.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. Clarens, Montreux, Switzerland.

Year of Election.

1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 34 Clarendon-road, Notting Hill, W.

Henry, Franklin. Portland-street, Manchester.

Henry, Mitchell. Stratheden House, Hyde Park, W.

1892. ‡Hepburn, David, M.D., F.R.S.E. The University, Edinburgh.

1855. *Hepburn, J. Gotch, LL.B., F.C.S. Oakfield Cottage, Dartford, Kent.

1855. ‡Hepburn, Robert. 9 Portland-place, W.

1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.

1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.

1892. *HERBERTSON, ANDREW J., F.R.G.S. Colinton, Midlothian.

1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool. Croxteth Lodge, Sefton Park, Liverpool.

1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.

1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.

1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham. Observatory House, Slough, Bucks.

1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.

1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.

1894. ‡HEWETSON, G. H. 39 Henley-road, Ipswich.

1890. ‡Hewetson, H. Bendelack, M.R.C.S., F.L.S. 11 Hanover-square, Leeds.

1894. ‡Hewins, W. A. S., M.A., F.S.S. 26 Cheyne-row, Chelsea, S.W.

1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.

1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.

1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.

1882. ‡HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.

1883. §Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. Swerford, Enstone, Oxfordshire.

1866. *Heymann, Albert. West Bridgford, Nottinghamshire.

1897.§§Heys, Thomas. 130 King-street West, Toronto, Canada.

1861. *Heywood, Arthur Henry. Elleray, Windermere.

1879. ‡Heywood, Sir A. Percival, Bart. Duffield Bank, Derby.

1886. §HEYWOOD, HENRY, J.P., F.C.S. Witla Court, near Cardiff.

1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.

1888. ‡Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.

1875. ‡HICKS, H., M.D., F.R.S., Pres.G.S. Hendon Grove, Hendon, N.W.

1898. §Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.

1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.

1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.

1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.

1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.

1864. *HIERN, W. P., M.A. Castle House, Barnstaple.

1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.

1891. §Higgs, Henry, LL.B., F.S.S. 12 Lyndhurst-road, Hampstead, N.W.

Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.

1894. §Hill, Rev. A. Du Boulay. East Bridgford Rectory, Nottingham.

Year of
Election.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
1898. §Hill, Charles. Clevedon.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *HILL, Rev. EDWIN, M.A., F.G.S. The Rectory, Cockfield, Bury St. Edmunds.
1887. ‡Hill, G. H., F.G.S. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1898. *Hill, Thomas Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in Mason Science College. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Sir Benjamin, Bart. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, Sir WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1881. §Hobbes, Robert George, M.R.I. Livingstone House, 374 Wandsworth-road, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. The Headlands, Scotland-lane, Horsforth, near Leeds.
1887. *Hobson, Bernard, B.Sc., F.G.S. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡*Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.*
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. ‡Hodgkinson, Arnold. 16 Albert-road, Southport.
1880. §§Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, S.E.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1898. §Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.

Year of
Election.

1896. ‡Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894.§§Hogg, A. F., M.A. 13 Victoria-road, Darlington.
1894. §Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1887. *Holder, Henry William, M.A. Owens College, Manchester.
1896. ‡Holder, Thomas. 2 Tithebarn-street, Liverpool.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. ‡Holgate, Benjamin, F.G.S. 4 Montpelier-terrace, Cliff-road, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E
1896.§§Holland, Mrs. Lowfields House, Hooton.
1898. §Holland, Thomas H., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. ***HOLMES, THOMAS VINCENT**, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1896. ‡Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. §Holterman, R. F. Brantford, Ontario, Canada.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡**HOOKER, Sir JOSEPH DALTON**, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1892. ‡Hooker, Reginald H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Rutford-road, Streatham, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Holy Trinity Vicarage, Blackheath Hill, Greenwich, S.E.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, W.
1884. ***HOPKINSON, CHARLES**. The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1871. ***HOPKINSON, JOHN**, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
Hornby, Hugh. Sandown, Liverpool.
1898. §Hornby, R., M.A. The High School, Newcastle, Staffordshire.
1885. ‡**HORNE, JOHN**, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Falmouth House, 20 Hyde Park-terrace, W.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. ***HORSLEY, VICTOR A. H.**, B.Sc., F.R.S., F.R.C.S. 25 Cavendish-square, W.
1884. *Hotblack, G. S. Bremdall, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S. Royal Observatory, Cape Town.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1896. ‡Hoult, J. South Castle-street, Liverpool.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.

Year of Election.

1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
1893. ‡Howard, F. T., M.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. *HOWARD, JAMES L., D.Sc. 86 St. John's-road, Waterloo, near Liverpool.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1889. §Howden, Robert, M.B., Professor of Anatomy in the University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Great Britain. Geological Survey Office, Edinburgh.
1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1898. §Howell, J. H. 104 Pembroke-road, Clifton, Bristol.
1891. ‡Howell, Rev. William Charles, M.A., Holy Trinity Parsonage, High Cross, Tottenham, Middlesex.
1886. §HOWES, Professor G. B., LL.D., F.R.S., F.L.S. Royal College of Science, South Kensington, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. 7 Princes Buildings, Clifton, Bristol.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §HOYLE, WILLIAM E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1898. §HUDLESTON, W. H., F.R.S., F.G.S. 8 Stanhope-gardens, S.W.
1888. ‡HUDSON, C. T., M.A., LL.D., F.R.S. 2 Barton-crescent, Dawlish.
1894. §Hudson, John E. 125 Milk-street, Boston, Massachusetts, U.S.A.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, S.W.
1858. *HUGGINS, Sir WILLIAM, K.C.B., D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse-hill, S.W.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. §§Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. ‡Hughes, John W. New Heys, Allerton, Liverpool.
1870. *Hughes, Lewis. Fenwick-chambers, Liverpool.
1891. ‡Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge. 18 Hills-road, Cambridge.
1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the City of Birmingham. Birmingham.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, W.
*Hulse, Sir Edward, Bart., D.C.L. Breamore House, Salisbury.
1897. §§Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.
1887. *HUMMEL, Professor J. J. 152 Woodsley-road, Leeds.

Year of Election.

1890. ‡Humphrey, Frank W. 63 Prince's-gate, S.W.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1898. §Hurle, J. Cooke. Southfield House, Brislington, Bristol.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Co. Down, Ireland.
1896. *Hurter, Dr. Ferdinand. Holly Lodge, Cressington, Liverpool.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Major E. R., R.E. 24 Waterloo-place, Southampton.
1894. *Hutchinson, A. Pembroke College, Cambridge.
1896. §§Hutchinson, W. B. 4 West-street, Southport.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.

1883. §Idris, T. H. W. Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1898. §Inskip, James. Clifton Park, Clifton, Bristol.
1892. ‡Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill Vicarage, Bishop's Stortford, Herts.

Year of
Election.
1888. *Isaac, J. F. V., B.A. Royal York Hotel, Brighton.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡*Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, W.*
1891. *ISMAY, THOMAS H. 10 Water-street, Liverpool.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *JACKSON, Professor A. H., B.Sc. 358 Collins-street, Melbourne, Australia.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. Harefield, 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. Harefield, 1 Morley-road, Southport.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James, F.R.Met.Soc. 34 Lonsdale-square, N.
1898. *Jackson, Sir John. 3 Victoria-street, S.W.
1869. §Jackson, Moses, J.P. 139 Lower Addiscombe-road, Croydon.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Villa Jaffe, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, W.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1896. §§James, O. S. 192 Jarvis-street, Toronto, Canada.
1858. ‡James, William C. Woodside, Plymouth.
1896. *Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §§Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S., V.P.C.S., Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1897. §Jeffrey, E. C., B.A. The University, Toronto, Canada.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, W.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, S.W.

Year of Election.

1873. §Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *JENKINS, Sir JOHN JONES, M.P. The Grange, Swansea.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
1897. §Jennings, W. T. 34 St. Vincent-street, Toronto, Canada.
1878. ‡*Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.*
1887. §JERVIS-SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡John, E. Cowbridge, Cardiff.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 1 Victoria-road, Clapham Common, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, N.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1898. *Johnson, W. Claude, M.Inst.C.E. The Dignaries, Blackheath, S.E.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, Sir H. H., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1896. *Joly, C. J., M.A. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., Professor of Astronomy in the University of Dublin and Royal Astronomer for Ireland. 39 Waterloo-road, Dublin.
1898. §Jones, Alfred L. Care of Messrs. Elder, Dempster & Co., Liverpool.
1881. ‡*Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.*
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. Science and Art Department, South Kensington, S.W.
1891. ‡Jones, D. Edgar, M.D. Spring Bank, Queen-street, Cardiff.

Year of
Election.
1890. §Jones, Rev. Edward, F.G.S. 7 Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1896. ‡Jones, E. Taylor. University College, Bangor.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, Waterloo, Liverpool.
1895. ‡Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, N.W.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, S.W.
1881. *JONES, J. VIRIAMU, M.A., B.Sc., F.R.S., Principal of the University College of South Wales and Monmouthshire, Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 17 Parson's Green, Fulham, S.W.
1896. §Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡*Jones, William Lester. 22 Newport-road, Cardiff.*
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1896. ‡Joyce, Joshua. 151 Walton-street, Oxford.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡JUDD, JOHN WESLEY, C.B., F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 22 Cumberland-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, N.
1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1859. ‡Kay, David, F.R.G.S. 78 Warwick-gardens, Kensington, W.
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. ‡Keene, Captain C. T. P., F.Z.S. 11 Queen's-gate, S.W.
1894. ‡Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1892. ‡*Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.*
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. 1 Savile-row, W.
1847. *KELVIN, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.

Year of Election.

1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 61 Cotham Brow, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, 17 Arundel-road, Eastbourne.
1891. ‡KENDALL, PERCY F., F.G.S., Professor of Geology in Yorkshire College, Leeds.
1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E. 17 Victoria-street, S.W., and 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, M.A., LL.D. Crown Lands Department, Toronto, Canada.
1884. §§Kennedy, George T., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1897. §§Kenrick, Frank B. Knesebeckstr. 3iii., Charlottenburg, Berlin.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, F.G.S. St. Thomas's Hospital, S.E.
1886. §KENWARD, JAMES, F.S.A. 43 Streatham High-road, S.W.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡KERMODE, PHILIP M. C. Ramsey, Isle of Man.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College, Glasgow.
1892. ‡Kerr, J. Graham. Christ's College, Cambridge.
1889. ‡Kerry, W. H. R. Wheatlands, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Rose Villa, Vale-road, Bowdon, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1897. §§Kiekelly, Dr. John, LL.D. 46 Upper Mount-street, Dublin.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Stonelands, East Grinstead.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
1883. *King, Joseph. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. 3 Clifton-park, Clifton, Bristol.

Year of Election.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. ‡King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1897.§§Kingsmill, Nichol. Toronto, Canada.
1875. §KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1897. §Kirkland, Thomas. 432 Jarvis-street, Toronto, Canada.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Devonshire-road, Liverpool.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1898. §KNOCKER, E. WOLLASTON, C. B. (LOCAL SECRETARY). Castle Hill House, Dover.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1897.§§Knowlton, W. H. 36 King-street East, Toronto, Canada.
1883. ‡*Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.*
1883. ‡*Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.*
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡KOHN, CHARLES A., Ph.D. University College, Liverpool.
1898. §Krauss, A. Hawthornden, Priory-road, Tyndall's Park, Clifton, Bristol.
1890. *Krauss, John Samuel, B.A. Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec.
1885. *Laing, J. Gerard. 111 Church-street, Chelsea, S.W.
1897.§§Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Old Lodge, Salisbury.
1887. ‡LAMB, HORACE, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, S.E.
1896. §Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. ‡Lamplugh, G. W., F.G.S. Geological Survey Office, Jermyn-street, S.W.

Year of Election.

1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.
1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1898. *Lang, William H. 10 Jedburgh-gardens, Kelvinside, Glasgow.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Director British Museum, Cromwell-road, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Physiography in the Mason Science College, Birmingham. 28 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. The Moat, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. 5 Pepy's-road, Wimbledon, Surrey.
1891. ‡Laurie, A. P. 49 Beaumont-square, E.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, S.W.
1884. §Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1889. §Laws, W. G., M.Inst.C.E. 65 Osborne-road, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1888. ‡Layard, Miss Nina F. 2 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, S.W.
1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. **Leatham, Edward Aldam.* 46 *Eaton-square, S.W.*
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1895. *Ledger, Rev. Edmund. Barham Rectory, Claydon, Ipswich.

Year of
Election.

1898. §LEE, ARTHUR, J.P. 10 Berkeley-square, Clifton, Bristol.
1861. ‡*Lee, Henry. Sedgeley Park, Manchester.*
1896. §Lee, Rev. H. J. Barton. South Park View, Ashburton, Devon.
1891.§§Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *LEES, CHARLES H., D.Sc. 6 Clyde-road, West Didsbury, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡*Lees, R. W. Moira-place, Southampton.*
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896. ‡Lees, William. 10 Norfolk-street, Manchester.
1883. *Leese, Miss H. K. 3 Lord-street West, Southport.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW. 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡Lehfeldt, Robert A. 28 South Molton-street, W.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1890. ‡Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1867. ‡*Leishman, James. Gateacre Hall, Liverpool.*
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, W.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1874. ‡*Lepper, Charles W. Laurel Lodge, Belfast.*
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. 51 Arcade-chambers, St. Mary's Gate, Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. §Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1897. §Lewis, Rev. J. Pitt, M.A. Care of G. A. Mackenzie, Esq., 18 Toronto-street, Toronto, Canada.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.

Year of Election.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1898. §Lippincott, R. Cann. Over Court, near Bristol.
1883. ‡Lisle, H. Claud. Nantwich.
1895. *LISTER, The Right Hon. Lord, D.C.L., Pres.R.S. 12 Park-crescent, Portland-place, W.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, N.E.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart., M.P. Penllegare, Swansea.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡*Lloyd, John. Queen's College, Birmingham.*
1886. ‡Lloyd, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt., F.R.S.E. 49A Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Woodgreen, Wednesbury.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1854. *LOBLEY, JAMES LOGAN, F.G.S. City of London College, Moorgate-street, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, W.C.
1867. *Locke, John. 42D Filmer-road, Fulham, S.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., F.R.S., F.R.A.S. Royal College of Science, South Kensington, S.W.
1886. *LODGE, ALFRED, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *LODGE, OLIVER J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 2 Grove-park, Liverpool.
1894. *Lodge, Oliver W. F. 2 Grove-park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1896. §Lomas, J. 16 Mellor-road, Birkenhead.
1876. ‡Long, H. A. Brisbane, Queensland.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Lowestoft.
1883. ‡*Longmaid, William Henry.* 4 *Rawlinson-road, Southport.*
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.

Year of Election.

1861. *Lord, Edward. Adamroyd, Todmorden.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1897.§§LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., F.R.S. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 29 Park-crescent, Monkgate, York.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, W.
1867. *Low, James F. Seaview, Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Cardiff.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1886. *Lowe, John Landor, M.Inst.C.E. Lansoar, Burton-road, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1897.§§*Lowry, George. Manchester.*
1881. ‡Lubbock, Arthur Rolfe. High Elms, Farnborough, R.S.O., Kent.
1853. *LUBBOCK, The Right Hon. Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.
1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1897.§§Lumsden, George E., F.R.A.S. 57 Elm-avenue, Toronto, Canada.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Coal Mining in Yorkshire College, Leeds. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. A. Audley-mansions, 44 Mount-street, W.
1864. *Lutley, John. Brockhampton Park, Worcester.
1898. §Luxmore, Dr. C. M. Reading College, Reading.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. ‡Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. §Lyster, A. G. Dockyard, Coburg Dock, Liverpool.
1896. ‡LYSTER, GEORGE F. Plas Isaf, Ruthin.
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, S.W.

Year of Election.

1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.I.C., F.C.S., Professor of Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, Edinburgh.

1876. *MACADAM, WILLIAM IVISON, F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.

1868. ‡MACALISTER, ALEXANDER, M.A., M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.

1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.

1896. ‡Macalister, N. A. S. 2 Gordon-street, W.C.

1897. §§McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.

1896. §MACALLUM, Professor A. B., Ph.D. The University, Toronto.

1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.

1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.

1883. §MacAndrew, William. Westwood House, near Colchester.

1866. *M'Arthur, Alexander. 79 Holland-park, W.

1896. ‡McArthur, Charles. Villa Marina, New Brighton, Chester.

1884. ‡Macarthur, D. Winnipeg, Canada.

1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.

1834. MACAULAY, JAMES, A.M., M.D. 4 Wynnstay-gardens, W.

1896. ‡MACBRIDE, Professor E. W., M.A. McGill University, Montreal, Canada.

1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.

1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.

1887. *McCarthy, James. Bangkok, Siam.

1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.

1884. ‡McCausland, Orr. Belfast.

1891. *McClean, Frank, M.A., LL.D., F.R.S., M.Inst.C.E. Rusthall House, Tunbridge Wells.

1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.

1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.

1872. *McClure, J. H., F.R.G.S. Whiston, Prescot.

1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.

1892. *McCowan, John, M.A., D.Sc. University College, Dundee.

1892. ‡McCrae, George. 3 Dick-place, Edinburgh.

1883. ‡*McCrossan, James. 92 Huskisson-street, Liverpool.*

1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn Fields, W.C.

1886. ‡McDonald, John Allen. Hillsboro' House, Derby.

1884. ‡MacDonald, Kenneth. Town Hall, Inverness.

1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.

1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.

MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.

1883. ‡*MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.*

1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.

1897. §§McEwen, William C. 9 South Charlotte-street, Edinburgh.

1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.

1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.

1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.

1897. §§McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.

1867. *M'Gavin, Robert. Ballumbie, Dundee.

1897. §§McGaw, Thomas. Queen's Hotel, Toronto, Canada

1888. ‡MacGeorge, James. 67 Marloes-road, Kensington, W.

Year of Election.

1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.

1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.

1885. ‡*Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.*

1884. *MACGREGOR, JAMES GORDON, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.

1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.

1867. *M'INTOSH, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.

1884. ‡McIntyre, John, M.D. Odiham, Hants.

1883. ‡Mack, Isaac A. Trinity-road, Bootle.

1884.§§Mackay, A. H., LL.D. Education Office, Halifax, Nova Scotia, Canada.

1885. §MACKAY, JOHN YULE, M.D., Professor of Anatomy in University College, Dundee.

1897.§§McKay, T. W. G., M.D. Oshawa, Ontario, Canada.

1896. *McKechnie, Duncan. Eccleston Grange, Preston.

1873. ‡MCKENDRICK, JOHN G., M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. 2 Florentine-gardens, Glasgow.

1883. ‡McKendrick, Mrs. 2 Florentine Gardens, Glasgow.

1897.§§McKenzie, John J. 61 Madison-avenue, Toronto, Canada.

1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, E.C.

1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.

1883. ‡Mackeson, Henry. Hythe, Kent.

1872. *Mackey, J. A. 175 Grange-road, S.E.

1867. ‡MACKIE, SAMUEL JOSEPH. 17 Howley-place, W.

1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.

1887. ‡MACKINDER, H. J., M.A., F.R.G.S. Christ Church, Oxford.

1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.

1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.

1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.

1872. *MCLACHLAN, ROBERT, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.

1896. ‡Maclagan, Miss Christian. Ravenscroft, Stirling.

1892. ‡MACLAGAN, Sir DOUGLAS, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.

1892. ‡Maclagan, Philip R. D. St. Catherine's, Liberton, Midlothian.

1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.

1873. ‡McLandsborough, John, F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.

1885. *M'LAREN, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.

1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.

1897.§§MacLaren, J. F. 380 Victoria-street, Toronto, Canada.

1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.

1897 §§MacLaren, Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.

1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.

1892. *MACLEAN, MAGNUS, M.A., F.R.S.E. The University, Glasgow.

1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.

1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.

1884. ‡McLennan, John. Lancaster, Ontario, Canada.

1868. §MCLEOD, HERBERT, F.R.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.

Year of Election.

1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMAHON, Lieut.-General C. A., F.R.S., F.G.S. 20 Nevern-square, South Kensington, S.W.
1883. ‡MACMAHON, Major PERCY A., R.A., F.R.S. 52 Shaftesbury-avenue, W.C.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, A. W. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
*MACRORY, EDMUND, M.A. 19 Pembridge-square, W.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *MAGNUS, Sir PHILIP, B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. ‡Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1883. ‡Maitland, P. C. 136 Great Portland-street, W.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1897. §Mance, Sir H. C. 32 Earl's Court-square, S.W.
1887. ‡MANCHESTER, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡*Mann, George. 72 Bon Accord-street, Aberdeen.*
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894.§§Manning, Percy, M.A., F.S.A. Watford, Herts.
1864. ‡Mansel-Pleydell, J. C., F.G.S. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. ‡Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡MARKHAM, Sir CLEMENTS R., K.C.B., F.R.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, S.W.
1894. ‡Markoff, Dr. Anatolius. 44 Museum-street, W.C.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.

Year of Election.

1881. *MARR, J. E., M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. Hurstwood, Roundhay, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 131 Warrender Park-road, Edinburgh.
1881. *Marshall, John, F.R.A.S. 2 Strattan-street, Leeds.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡*Marshall, John Ingham Fearby. 28 St. Saviourgate, York.*
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1884. §Martin, N. H., J.P., F.L.S. Ravenswood, Low Fell, Gateshead-on-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.
1890. §Martindale, William. 19 Devonshire-street, Portland-place, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡*Mason, James, M.D. Montgomery House, Sheffield.*
1896. ‡Mason, Philip B., F.L.S., F.Z.S. Burton-on-Trent.
1893. *Mason, Thomas. 6 Pelham-road, Sherwood Rise, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. University of Melbourne, Victoria, Australia.
1898. §Masterman, A. T. University of St. Andrews, N.B.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1898. §Mathews, E. R. Norris. Cotham-road, Cotham, Bristol.
1894. ‡MATHEWS, Prof. G. B., M.A., F.R.S. Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 21 Augustus-road, Edgbaston, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.

Year of Election.

1885. ‡MATTHEWS, JAMES. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1893. ‡Mavor, Professor James, M.A., LL.D. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §§Maxim, Hiram S. 18 Queen's Gate-place, Kensington, S.W.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1887. ‡*Maxwell, James. 29 Princess-street, Manchester.*
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., LL.D., F.R.S., F.R.A.S. Marine House, Beach-road, St. Luke's, Jersey.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1896. §Mellor, G. H. Weston, Blundell Sands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1896. ‡Menneer, R. R. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, E.C.
1879. ‡MERIVALE, JOHN HERMAN, M.A. Togston Hall, Acklington.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1896. §§Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S., Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 46 Windsor-road, Ealing, W.
1894. *MIERS, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. ‡MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., F.R.S.E., Librarian R.G.S. 109 West End-lane, Hampstead, N.W.

Year of Election.

1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1875. ‡Miller, George. Brentry, near Bristol.
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1895. §Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. §§Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. §Mills, Mansfeldt H., M.Inst.C.E., F.G.S. Sherwood Hall, Mansfield.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1898. *Milner, S. Roslington, B.Sc. Owens College, Manchester.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, N.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡MIVART, ST. GEORGE, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. 77 Inverness-terrace, W.
1895. *Moat, William, M.A. Johnson, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Right Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *MOND, LUDWIG, Ph.D., F.R.S., F.C.S. 20 Avenue-road, Regent's Park, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. ‡Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.
1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1894. §§Moore, Harold E. 41 Bedford-row, W.C.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.

Year of Election.

1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
1857. **Moore, Rev. William Prior.* *Carrickmore, Galway, Ireland.*
1896. *Mordey, W. M. Princes-mansions, Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. §MORGAN, C. LLOYD, F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 61 Hope-street, Liverpool.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882.§§Morgan, Thomas, J.P. Cross House, Southampton.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, S.W.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn, R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Daniel, C.M.G., M.A., D.Sc., F.L.S. 12 Cumberland-road, Kew.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡*Morris, John.* *4 The Elms, Liverpool.*
1896. *Morris, J. T. 13 Somers-place, W.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 209 Edge-lane, Liverpool.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hockliffe Grange, Leighton Buzzard.
1896. *Morton, William B., Professor of Natural Philosophy in Queen's College, Belfast.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. 5 Chiswick-place, Eastbourne.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., M.A. 19 Peak-hill, Sydenham, S.E.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866. ‡MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.

Year of
Election.

1878. *MOULTON, J. FLETCHER, M.A., Q.C., M.P., F.R.S. 57 Onslow-square, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. The Wigwam, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Cheltenham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1894. ‡Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. Demster House, Perthshire.
1874. ‡MUIR, M. M. PATTISON, M.A. Caius College, Cambridge.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. 14 Kerrsland-street, Hillhead, Glasgow.
1883. ‡MULHALL, MICHAEL G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. ‡MÜLLER, The Right Hon. F. MAX, M.A., Professor of Comparative Philology in the University of Oxford. 7 Norham-gardens, Oxford.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
1897.§§Mullins, W. E. Preshute House, Marlborough, Wilts.
1898. §Mumford, C. E. Bury St. Edmunds.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, E.C.
1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.
1898. §Munro, John, Professor of Mechanical Engineering in the Merchant Venturers' Technical College, Bristol.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., Ph.D., F.R.S., F.R.S.E. Challenger Lodge, Wardie, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1874. §Musgrave, Sir James, Bart., J.P. Drumglass House, Belfast.
1897.§§Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L., M.A., F.S.A. Christ Church, Oxford.

Year of Election.

1886. ‡NAGEL, D. H., M.A. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 34 Queen-street, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U.S.A.
1896. ‡Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1887. ‡*Neill, Joseph S. Claremont, Broughton Park, Manchester.*
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1897.§§Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1898. §Nevill, Rev. J. H. N. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1889. §Newstead, A. H. L., B.A. Rose Villa, Prospect-road, Snakes-lane, Woodford.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1883. ‡*Nias, Miss Isabel. 56 Montagu-square, W.*
1882. ‡*Nias, J. B., B.A. 56 Montagu-square, W.*
1867. ‡Nicholl, Thomas. Dundee.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.R.S., F.L.S., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885.§§Nicol, W. W. J., M.A., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. ‡Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1863. *NOBLE, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1879. ‡Noble, T. S. Lendal, York.
1886. ‡Nock, J. B. Mayfield, Penns, near Birmingham.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.

Year of Election.

1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.

1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhampstead.

1888. ‡Norman, George. 12 Brock-street, Bath.

1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.

1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.

1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.

1881. ‡North, William, B.A. 84 Micklegate, York.

NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.

1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.

1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. 98 Anglesea-road, Ipswich.

1861. ‡Noton, Thomas. Priory House, Oldham.

Nowell, John. Farnley Wood, near Huddersfield.

1896.§§Nugent, the Right Rev. Monsignor. 18 Adelaide-terrace, Waterloo, Liverpool.

1887. ‡Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.

1882. §Obach, Eugene, Ph.D., F.I.C., F.L.S., F.C.S. 113 Victoria-road, Old Charlton, Kent.

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.

O'Callaghan, George. Tallas, Co. Clare.

1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.

1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.

1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.

1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.

1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.

1894. §Ogden, James. Kilner Deyne, Rochdale.

1896.§§Ogden, Thomas. 4 Prince's-avenue, Liverpool.

1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.

1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.

1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.

1893. ‡Ogilvie, Miss Maria M., D.Sc. Gordon's College, Aberdeen.

1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.

*Ogle, William, M.D., M.A. The Elms, Derby.

1884. ‡O'Halloran, J. S., C.M.G. Royal Colonial Institute, Northumberland-avenue, W.C.

1881. ‡Oldfield, Joseph. Lendal, York.

1887. ‡Oldham, Charles. Romiley, Cheshire.

1896. ‡Oldham, G. S. Town Hall, Birkenhead.

1892. ‡Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.

1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.

1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.

1893. *Oldham, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, E.C.

1892. ‡Oliphant, James. 50 Palmerston-place, Edinburgh.

1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.

1887. ‡Oliver, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. The Tower House, Tite-street, Chelsea, S.W.

Year of Election.

1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *OMMANNEY, Admiral Sir ERASMUS, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, W.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1872. ‡Onslow, D. Robert. New University Club, St. James's, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit in the University of Berlin.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡*Ord, Miss Maria. Fern Lea, Park-crescent, Southport.*
1883. ‡Ord, Miss Sarah. 2 Pembroke-vale, Clifton, Bristol.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡*Orpen, Miss.* 58 *Stephen's-green, Dublin.*
1884. *Orpen, Lieut.-Colonel R. T., R.E. Care of G. H. Orpen, Esq., Erpingham, Bedford Park, Chiswick.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1897. §§Osborne, James K. 40 St. Joseph-street, Toronto, Canada.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1897. §§Osler, E. B., M.P. Rosedale, Toronto, Canada.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, WILLIAM, M.D., F.R.S. Johns Hopkins University, Baltimore, U.S.A.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1898. §Paget, The Right Hon. Sir R. H., Bart. Cranmore Hall, Shepton Mallet.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1883. §§Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.

Year of Election.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1898. §Parker, G., M.D. 14 Pembroke-road, Clifton, Bristol.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1865. *Parsons, Charles Thomas. Mountlands, Norfolk-road, Edgbaston, Birmingham.
1878. ‡PARSONS, Hon. C. A., F.R.S. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1898. §Partridge, Miss Josephine M. Girton College, Cambridge.
1898. §Pass, Alfred C. Clifton Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1897. §§Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896. ‡Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1897. §Paton, D. Noël, M.D. 33 George-square, Edinburgh.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. Care of the Sheddon Co., Montreal, Canada.
1871. *Patterson, A. Henry. 16 Ashburn-place, S.W.
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1867. ‡Pattison, Samuel Rowles. 11 Queen Victoria-street, E.C.
1879. *Patzer, F. R. Winton-square, Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, F. WILLIAM, M.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. 1 Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. 1 Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.
1881. *PEARCE, HORACE, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.

Year of Election.

1888. §Pearce, Rev. R. J., D.C.L. The Vicarage, Bedlington, R.S.O., Northumberland.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1898. §Pearson, George. Baldwin-street, Bristol.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, Richard. 57 Bootham, York.
1883. **Pearson, Thomas H.* *Redclyffe, Newton-le-Willows, Lancashire.*
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡PEEK, Sir CUTHBERT E., M.A., F.S.A. 22 Belgrave-square, S.W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, S.W.
1861. *Peile, George. Greenwood, Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
1887. §PENDLEBURY WILLIAM H., M.A., F.C.S. (LOCAL SECRETARY). 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1897. §§PENHALLOW, Professor D. P., M.A. McGill University, Montreal, Canada.
1896. §Pennant, P. P. Nantlys, St. Asaph.
1898. §Pentecost, Harold. Clifton College, Bristol.
1881. ‡*Penty, W. G.* *Melbourne-street, York.*
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
1898. §Percival, Francis W., M.A., F.R.G.S., 2 Southwick-place, W.
1895. §Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Lower Kingswood, Reigate.
1894. ‡Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Woodhouse Cliff, Leeds.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡PERKIN, WILLIAM HENRY, jun., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P. University College, Cardiff.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.

Year of Election.

1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1897. §§Peters, Dr. George A. 171 College-street, Toronto, Canada.
1898. §Pethick, William. Woodside, Stoke Bishop, Bristol.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. §PETRIE, W. M. FLINDERS, D.C.L., Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1896. §§Philip, George, jun. 14 Holly-road, Fairfield, Liverpool.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, George-lane, Woodford, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1898. §Philps, Captain Lambe. 7 Royal-terrace, Weston-super-Mare.
1868. ‡*Phipson, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.*
1884. *Pickard, Rev. H. Adair, M.A. Airedale, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1896. ‡Picton, W. H. College-avenue, Crosby, Liverpool.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 12 King's Bench-walk, Temple, E.C.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, W.
1873. ‡Pike, W. H., M.A., Ph.D., Professor of Chemistry in the University of Toronto, Canada.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
1896. *Pilling, William. Rosario, Keene-road, West Worthing.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, S.E.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.

Year of Election.

1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, E.C.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. Rushmore, Salisbury.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G. (Messrs. King & Co., Pall Mall, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 38 Grosvenor-street, W.
1898. §Playne, H. C. 28 College-road, Clifton, Bristol.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, S.W.
1893. ‡Plowright, Henry J. Brampton Foundries, Chesterfield.
1897.§§Plummer, J. H. Bank of Commerce, Toronto, Canada.
1898. §Plummer, W. E. The Observatory, Bidston, Birkenhead.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, S.W.
1896.§§Pollard, James. High Down, Hitchin, Herts.
1898. §Pollen, Rev. G. C. H., F.G.S. St. Beuno's College, St. Asaph, North Wales.
1896. *Pollex, Albert. Dale End, Cavendish Park, Rockferry.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, R.S.O., Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1892. §Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Yorkshire College, Leeds.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Brynmill-crescent, Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, St. Ann-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡POYNTING, J. H., D.Sc., F.R.S., Professor of Physics in the Mason College, Birmingham.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1891. ‡*Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.*
1869. *PREECE, WILLIAM HENRY, C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.

Year of Election.

1888. *Preece, W. Llewellyn. Tan-y-bryn, Rusholme-road, Putney Heath, S.W.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1894. §Prentice, Manning, F.C.S. Woodfield, Stowmarket.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. Journal-chambers, Pelham-street, Nottingham.
1893. §PRESTON, Professor THOMAS, F.R.S. Bardowie, Orwell Park, Dublin.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., D.D., F.R.S., F.R.A.S., Master of Pembroke College, Oxford.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1897. *Price, W. A., M.A. Teign House, Westcombe Park-road, S.E.
1897.§§Primrose, Dr. Alexander. 196 Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 45 St. Giles, Norwich.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1898. §Proctor, H. Faraday. Temple Backs, Bristol.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Slade-road, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Castlewood, Park-road, Moseley, Birmingham.
1887. §PUMPHREY, WILLIAM. 2 Oakland-road, Redland, Bristol.
1885.§§PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. §Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

Year of Election.

1896. ‡Quaill, Edward. 3 Palm-grove, Claughton.
1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor Walter J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
1877. ‡*Radford, George D. Mannamead, Plymouth.*
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, W.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh. Royal College of Science, Dublin.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.A.S., M.R.I.A., Radcliffe Observatory, Oxford.
1863. ‡RAMSAY, ALEXANDER. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., Professor of Chemistry in University College, London. 12 Arundel-gardens, W.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, W.
1868. *Ransom, Edwin, F.R.G.S. 22 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S., Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. §Rathbone, R. R. Glan y Menai, Anglesey.
1895. ‡RATHBONE, W., LL.D. Green Bank, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 2 York-mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, S.W.
1886. ‡Rawson, W. Stepney, M.A. 68 Cornwall-gardens, Queen's-gate, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. §§Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.

Year of Election.

1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree. Mayfield House, Ashbourne.
1896. §Read, Charles H., F.S.A. British Museum, W.C.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, E.C.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡REED, Sir EDWARD JAMES, K.C.B., F.R.S. 75 Harrington-gardens, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. 15 Merridale-lane, Wolverhampton.
1891. §Rees, I. Treharne, M.Inst.C.E. Highfield, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897.§§Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.L.S., F.G.S. 28 Jermyn-street, S.W.
1892. ‡REID, E. WAYMOUTH, B.A., F.R.S., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1897. §Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1893. ‡Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1894. ‡RENDALL, G. H., M.A. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Bank House, 135 Lord-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 19 Lady Barn-road, Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. Cliff Lodge, Hyde Park, Leeds.
1896. ‡Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896. §Rhodes, Albert. Field Hurst, Liversidge, Yorkshire.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1858. *Rhodes, John. Potternewton House, Chapel Allerton, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. ‡Rhodes, John George. Warwick House, 46 St. George's-road, S.W.

Year of Election.

1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro, 14, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D.
1869. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh. Bootham School, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡*Richardson, W. B. Elm Bank, York.*
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Heathwood, Leighton Buzzard.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1894. §RIDLEY, E. P. 6 Paget-road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 152 Blomfield-terrace, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1869. *Rivington, John. Babbicombe, near Torquay.
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, London, N.W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1894. *Roberts, Miss Janora. 5 York-road, Birkdale, Southport.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 31 North-road, Cowley Hill, St. Helens.
1883. ‡ROBERTS, Sir WILLIAM, M.D., F.R.S. 8 Manchester-square, W.
1868. *ROBERTS-AUSTEN, W. CHANDLER, C.B., D.C.L., F.R.S., V.P.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. (GENERAL SECRETARY.) Royal Mint, E.

Year of
Election.

1883. ‡Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1897. §§Robertson, Sir George S., K.C.S.I. Care of Messrs. Wm. Watson & Co., 7 Waterloo-place, S.W.
1897. §§Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, N.W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1898. §Robinson, Charles E., M.Inst.C.E. Richmond Lodge, Torquay.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1897. §§Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, S.W.
1888. ‡Robinson, John. 8 Vicarage-terrace, Kendal.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. ‡Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. E. S. Talbot, D.D., Lord Bishop of. Kennington Park, S.E.
1896. §Rock, W. H. 73 Park-road East, Birkenhead.
1896. ‡Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. §ROGERS, BERTRAM, M.D. 11 York-place, Clifton, Bristol.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Tresleigh, St. Austell, Cornwall.
1884. *Rogers, Walter M. Lamorva, Falmouth.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1897. §§Rogerson, John. Barrie, Ontario, Canada.
1876. ‡ROLLIT, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. 12 Cumberland-place, Southampton.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1881. *Roper, W. O. Bank-buildings, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. 10 Bramham-gardens, S.W.

Year of Election.

1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, S.W.
1894. *Rose, T. K., D.Sc. 9 Royal Mint, E.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1897.§§Ross, Hon. Alexander M. 3 Walmer-road, Toronto, Canada.
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.G.S. 8 Collingham-gardens, Cromwell-road, S.W.
1897.§§Ross, Hon. G.W., Minister of Education for the Province of Ontario. Toronto, Canada.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. §Roth, H. Ling. 32 Prescot-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell, F.L.S. Orston House, Sherwood Rise, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 54 Westbourne-villas, West Brighton.
1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *ROWNTREE, JOHN S. Mount Villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1875. *RÜCKER, A. W., M.A., D.Sc., Sec.R.S., Professor of Physics in the Royal College of Science, London. 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Union-court Chambers, Old Broad-street, E.C.
1896. ‡Rundell, T. W. 25 Castle-street, Liverpool.
1887.§§Ruscoe, John. Ferndale, Gee Cross, near Manchester.
1847. ‡RUSKIN, JOHN, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, S.E.
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S. 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897.§§Rutherford, A. Toronto, Canada.
1891. §Rutherford, George. Dulwich House, Pencisely-road, Cardiff.

Year of Election.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Edinburgh.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N. 41 Cromwell-gardens, S.W.
1875. ‡*Ryalls, Charles Wagner, LL.D. 3 Brick-court, Temple, E.C.*
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1897.§ §Ryerson, G. S., M.D. Toronto, Canada.
1898. §Ryland, C. J. Southerndon House, Clifton, Bristol.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, E.C.
1885. ‡Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1886. §St. Clair, George, F.G.S. 225 Castle-road, Cardiff.
1893. ‡SALISBURY, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S. 20 Arlington Street, S.W.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡*Salmond, Robert G. Kingswood-road, Upper Norwood, S.E.*
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. ‡SAMUELSON, The Right Hon. Sir BERNHARD, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §SANDERSON, J. S. BURDON, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Regius Professor of Medicine in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. Tylehurst, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Down Lodge, Fairlight, Hastings.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. ‡Sargant, W. L. Quarry Hill, Reigate.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, Dr. William. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.

Year of Election.

1887. §Savage, Rev. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1887. §SAYCE, Rev. A. H., M.A., D.D., Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *SCHÄFER, E. A., LL.D., F.R.S., M.R.C.S., Professor of Physiology in University College, London. (GENERAL SECRETARY.) Croxley Green, Rickmansworth.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. ‡Schloss, David F. 1 Knaresborough-place, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. Lyme House, Marsland-road, Brooklands, Cheshire.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, W.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S. Royal Institution, Albemarle-street, W.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angas, D.Sc. Lancashire College, Whalley Range, Manchester.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1897. §Scott, James. 173 Jameson-avenue, Toronto, Canada.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.R.Met.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1895. §Scott-Elliot, G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. 2 Langland-gardens, Finchley-road, N.W.
1890. §§Searle, G. F. C., M.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡SEDGWICK, ADAM, M.A., F.R.S. Trinity College, Cambridge.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, W.

Year of Election.

1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1893. ‡SELBY-BIGGE, L. A., M.A. University College, Oxford.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, E.C.
1897. §§Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.
1884. ‡SELWYN, A. R. C., C.M.G., F.R.S. Ottawa, Canada.
1885. ‡Semple, Dr. A. United Service Club, Edinburgh.
1887. §Semple, James C., F.R.G.S., M.R.I.A. 2 Marine-terrace, Kingstown, Co. Dublin.
1892. ‡*Semple, William. Gordon's College, Aberdeen.*
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1888. *Sennett, Alfred R., A.M.Inst.C.E. The Chalet, Portinscale-road, Putney, S.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. ‡Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1895. *Seton-Karr, H. W. Spencer House, Wimbledon, Surrey.
1892. §SEWARD, A. C., M.A., F.R.S., F.G.S. Westfield, Huntingdon-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 St. Charles-square, Ladbroke Grove-road, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1896. ‡Sharp, Mrs. E. 65 Sankey-street, Warrington.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
1883. ‡Sharples, Charles H. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. ‡Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Halberton, near Tiverton, Devon.
1837. §§Shaw, Saville, F.C.S. College of Science, Newcastle-upon-Tyne.
1883. *SHAW, W. N., M.A., F.R.S. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1878. ‡Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A., F.R.S. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1885. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.

Year of Election.

1896.§§SHERRINGTON, C. S., M.D., F.R.S., Professor of Physiology in University College, Liverpool. 16 Grove-park, Liverpool.

1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.

1886. ‡Shield, Arthur H. 35A Great George-street, S.W.

1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.

1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.

1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.

1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.

1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.

1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.

1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.

1870. *SHOOLBRED, J. N., M.Inst.C.E. 47 Victoria-street, S.W.

1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, W.C.

1897.§§Shore, Dr. Lewis E. St. John's College, Cambridge.

1875. ‡SHORE, THOMAS W., F.G.S. Hartley Institution, Southampton.

1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital, E.C.

1897.§§Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.

1889. ‡Sibley, Walter K., B.A., M.B. 7 Upper Brook-street, W.

1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.

1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.

1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.

1877. *Sidebotham, Joseph Watson, M.P. Erlesdene, Bowdon, Cheshire.

1885. *SIDGWICK, HENRY, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.

Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.

1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, W.

1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.

1859. ‡Sim, John. Hardgate, Aberdeen.

1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.

1898. §Simmons, Henry. Kingsland House, Whiteladies-road, Clifton, Bristol.

1862. ‡Simms, James. 138 Fleet-street, E.C.

1874. ‡Simms, William. Upper Queen-street, Belfast.

1876. ‡Simon, Frederick. 24 Sutherland-gardens, W.

1887. *Simon, Henry. Lawnhurst, Didsbury, near Manchester.

1893. ‡Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.

1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.

1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.

1887. ‡Simpson, F. Estacion Central, Buenos Ayres.

1859. ‡Simpson, John. Maykirk, Kincardineshire.

1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.

1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S. 9 Barton-street, West Kensington, W.

1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.

1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.

1896. *Simpson, W., F.G.S. The Gables, Halifax.

1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.

1874. ‡Sinclair, Thomas. Dunedin, Belfast.

1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.

1897. §Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.

Year of Election.

1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. ‡Sisley, Richard, M.D. 11 York-street, Portman-square, W.
1879. ‡Skertchly, Sydney B. J. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1898. §Skinner, Sidney. Cromwell House, Trumpington, Cambridgeshire.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. 13 Hyde Park-gate, S.W.; and Northbrook Park, near Exeter.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S. 65 Pembroke-road, Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., B.Sc., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. ‡Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1898. §Smeeth, W. F., M.A., F.G.S. Mysore, India.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡SMITH, ADAM GILLIES, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago, Illinois, U.S.A.
1897.§§Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1872. *SMITH, BASIL WOODD, F.R.A.S. Branch Hill Lodge, Hampstead Heath, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897.§§Smith, Sir Frank. Toronto, Canada.
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
1897. §Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, W.

Year of Election.

1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, E.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡SMITH, ROBERT H., Assoc.M.Inst.C.E. 52 Victoria-street, S.W.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1873. ‡Smith, Sir Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1894. §Smith, T. Walrond. 32 Victoria-street, Westminster, S.W.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, W.C.
1896. *Smith, Rev. W. Hodson. 31 Esplanade-gardens, Scarborough.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton Down, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡SMITHELLS, ARTHUR, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1892. §Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
1882. ‡Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1888. ‡Snell, Albion T. Brightside, Salusbury-road, Brondesbury, N.W.
1878. §§Snell, H. Saxon. 22 Southampton-buildings, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1898. §Snook, Miss L. B. V. 13 Clare-road, Cotham, Bristol.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Oxford.
1892. *Somervail, Alexander. Torquay.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1892. ‡Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1898. §Southby, Rev. R. W., M.A. 4 Royal-park, Clifton, Bristol.
1887. §Sowerbutts, Eli, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.

Year of Election.

1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884.§§Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newbiggin House, Kenton, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 107 Sloane-street, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1897.§§Squire, W. Stevens, M.D. Charendon House, St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. 15 Wolseley-road, Crouch End, N.
1897.§§Stafford, Joseph. Morrisburg, Ontario, Canada.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. Royal Mint, E.
1893. ‡Staples, Sir Nathaniel, Bart. Lisson, Cookstown, Ireland.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1876. ‡Starling, John Henry, F.C.S. 32 Craven-street, Strand, W.C.
1898. §Stather, J. W. 16 Louis-street, Hull.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 169 Gloucester-terrace, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡*Stelfox, John L. 6 Hilton-street, Oldham, Manchester.*
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.

Year of Election.

1880. *Stevens, J. Edward, LL.B. Le Mayals, near Swansea.
1886. ‡*Stevens, Marshall. Highfield House, Urmston, near Manchester.*
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C. Westoe, South Shields.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. **Stewart, A. H. St. Thomas's Hospital, London, S.E.*
1864. ‡STEWART, CHARLES, M.A., F.R.S., F.L.S., Hunterian Professor and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn Fields, W.C.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 14 Windsor-terrace West, Glasgow.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. ‡Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1898. §Stoddart, F. Wallis, F.I.C. Grafton Lodge, Sneyd Park, Bristol.
1898. *Stokes, Professor G. J., M.A. Riversdale, Sunday's Well, Cork.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡*Stone, E. D., F.C.S 19 Lever-street, Piccadilly, Manchester.*
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, N.W.
1883. ‡*Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, W.*
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1895. *Stoney, Miss Edith A. 8 Upper Hornsey Rise, N.
1878. *Stoney, G. Gerald. 7 Roxburgh-place, Heaton, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, N.
1876. §Stopes, Henry. Mansion House, Swanscombe, Greenhithe, Kent.
1883. ‡Stopes, Mrs. Mansion House, Swanscombe, Greenhithe, Kent.
1887. *Storey, H. L. Lancaster.
1884. §§Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. 3 Park-lane, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General SIR RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, W.

Year of Election.

1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1889. ‡*Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.*
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1898. §Strangeways, C. Fox. Leicester.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, S.W.
1889. ‡Streatfeild, H. S., F.G.S. Ryhope, near Sunderland.
1879. ‡Strickland, Sir Charles W., Bart., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M. Helstonleigh, Champion Park, Denmark Hill, S.E.
1887. *Stroud, Professor H., M.A., D.Sc. College of Science, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, Sir JOHN, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. St. Matthew, Bayswater, 5 Prince's-square, W.
1892. ‡Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. ‡Stubbs, Arthur G. Sherwood Rise, Nottingham.
1896. ‡Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1888. *Stubbs, Rev. E. Thackeray, M.A. Grove Lea, Lansdowne-grove, Bath.
1885. ‡Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1897. §§Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. University College, Nottingham.
1898. §Sully, T. N. 12 Downleaze, Sneyd Park, Bristol.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884 ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1898. §Sutton, William, M.D. 6 Camden-crescent, Dover.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1881. §SWAN, JOSEPH WILSON, M.A., F.R.S. 58 Holland-park, W.
1897. §Swanston, William, F.G.S. Queen-street, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡*Sweeting, Rev. T. E. 50 Roe-lane, Southport.*
1887. §SWINBURNE, JAMES, M.Inst.C.E. 66 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.

Year of Election.

1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1890.§§SWINHOE, Colonel C., F.L.S. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. The Municipal Technical School, Gravesend.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. ‡Sykes, E. R. 3 Gray's Inn-place, W.C.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. 19 Manor-street, Ardwick, Manchester.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. Queen's College, Belfast.
1881. **Symington, Thomas. Wardie House, Edinburgh.*
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, N.W.
1855. *SYMONS, WILLIAM. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896.§§Tabor, J. M. 20 Petherton-road, Canonbury, N.
1898. §Tagart, Francis. 199 Queen's-gate, S.W.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1877. *TAIT, LAWSON, F.R.C.S. 195 Newhall-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.S.S. 6 Rossetti-mansions, Cheyne-walk, S.W.
1894. ‡Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1893. ‡*Talbot, Herbert, M.I.E.E.* 19 *Addison-villas, Addison-street, Nottingham.*
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1890. ‡TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1897.§§Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G. 167 Adelaide-road, N.W.
1883. *Tapscott, R. Lethbridge, Assoc.M.Inst.C.E., F.G.S., F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. 190 Old Christchurch-road, Bournemouth.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. §Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. *Taylor, H. A. 69 Addison-road, Kensington, W.
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. The Old Palace, Richmond, Surrey.

Year of Election.

1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡Taylor, W. F. Bhootan, Whitehorse-road, Croydon, Surrey.
1894. *Taylor, W. W. 10 King-street, Oxford.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, S.W.
1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡TEMPLE, The Right Hon. Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.S., F.R.G.S. Athenæum Club, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894.§§Terras, J. A., B.Sc. Royal Botanic Gardens, Edinburgh.
1882. ‡Terrill, William. 42 St. George's-terrace, Swansea.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, W.C.
1885. ‡Thin, Dr. George. 22 Queen Anne-street, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891.§§Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1884. ‡THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1881. ‡THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 86 Breakspear's-road, Brockley, S.E.
1880. *Thomas, Joseph William, F.C.S. 2 Hampstead Hill-mansions, N.W.
1898. §Thomas, Rev. W. Bristol School Board, Guildhall, Bristol.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.

Year of Election.

1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., C.B., Professor of Zoology in University College, Dundee. University College, Dundee.
1896. *Thompson, Edward P. Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. 53 Croxteth-road, Liverpool.
1897.§§Thompson, J. Barclay. 37 St. Giles's, Oxford.
1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.
1883. *Thompson, T. H. Redlynet House, Green Walk, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., Professor of Physiology in Queen's College, Belfast.
1896. §Thompson, W. P. 6 Lord-street, Liverpool.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1868. §THOMSON, JAMES, F.G.S. 6 Stewart-street, Shawlands, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1891. ‡Thomson, John. 70A Grosvenor-street, W.
1896. ‡Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.
1890. §Thomson, J. Arthur, M.A., F.R.S.E., Lecturer on Zoology at the School of Medicine, Edinburgh. 11 Ramsay-garden, Edinburgh.
1883. ‡THOMSON, J. J., M.A., D.Sc, F.R.S., Professor of Experimental Physics in the University of Cambridge. 6 Scrope-terrace, Cambridge.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S., Sec.C.S., Professor of Chemistry in King's College, London. 85 Addison-road, W.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1897.§§Thorburn, James, M.D. Toronto, Canada.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Sir Thomas. Dundee.
1898. §Thornton, W. M. Leigh View, Stoke Bishop, Bristol.
1883.§§Thorowgood, Samuel. Castle-square, Brighton.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. Undercliffe, Holmfirth.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.

Year of Election.

1864. *THORP, WILLIAM, B.Sc., F.C.S. 22 Sinclair-gardens, West Kensington, W.

1871. ‡THORPE, T. E., Ph.D., LL.D., F.R.S., F.R.S.E., Treas.C.S., Principal of the Government Laboratories, Clement's Inn-passage, W.C.

1898. §Thorpe, William George. 4 Elm-court, Temple, E.C.

1883. §Threlfall, Henry Singleton, J.P. 12 London-street, Southport.

1896. §Thrift, William Edward. 80 Grosvenor-square, Rathmines, Dublin.

1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.

1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.

1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.

1873. *TIDDEMAN, R. H., M.A., F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.

1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London. 9 Ladbroke-gardens, W.

1873. ‡Tilghman, B. C. Philadelphia, U.S.A.

1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.

1883. ‡Tillyard, Mrs. Fordfield, Cambridge.

1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.

1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Yorkshire.

1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.

1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.

1897.§§Todhunter, James. 85 Wellesley-street, Toronto, Canada.

1889. §Toll, John M. 49 Newsham-drive, Liverpool.

1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.

1896. ‡Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.

1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.

1887. ‡Tonge, James, F.G.S. Woodbine House, West Houghton, Bolton.

1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.

1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.

1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, S.W.

1887. ‡*Topham, F.* 15 *Great George-street, S.W.*

1886. ‡*Topley, Mrs. W.* 13 *Havelock-road, Croydon.*

1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.

1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.

1884. ‡*Torrance, John F. Folly Lake, Nova Scotia, Canada.*

1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.

Towgood, Edward. St. Neots, Huntingdonshire.

1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.

1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.

1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.

1877. ‡Tozer, Henry. Ashburton.

1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.

1883. ‡TRAILL, A., M.D., LL.D. Ballylough, Bushmills, Ireland.

1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.

1868. ‡TRAQUAIR, RAMSAY H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.

1891. ‡Trayes, Valentine. Maindell Hall, Newport, Monmouthshire.

1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.

Year of Election.

1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §§Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1871. ‡TRIMEN, ROLAND, F.R.S., F.L.S., F.Z.S. 88 Onslow-gardens, Queen's Gate, S.W.
1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham, Government Electrician and Inspector. The Treasury, Cape Town.
1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *TROUTON, FREDERICK T., M.A., D.Sc., F.R.S. Trinity College, Dublin.
1898. §Trow, Albert Howard. Glanhafren, Penarth.
1896. §Truell, Henry Pomeroy, M.B., F.R.C.S.I. Clonmannon, Ashford, Co. Wicklow.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, Sir J. Batty, M.D. Cupar, Fifeshire.
1887. ‡*Tuke, W. C* 29 *Princess-street, Manchester.*
1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B. 17 Victoria-street, S.W.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1896. ‡*Turner, Alfred. Elmswood Hall, Aigburgh, Liverpool.*
1893. §TURNER, DAWSON, M.B. 37 George-square, Edinburgh.
1882. ‡Turner, G. S. Pitcombe, Winchester-road, Southampton.
1883. ‡Turner, Mrs. G. S. Pitcombe, Winchester-road, Southampton.
1894. *TURNER, H. H., M.A., B.Sc., F.R.S., Sec. R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. Ravenhurst, Rowley Park, Stafford.
1863. *TURNER, Sir WILLIAM, M.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.
1890. *Turpin, G. S., M.A., D.Sc. School House, Swansea.
1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.
1898. §Twigg, H. W. 65 Victoria-street, Bristol.
1888. §Tyack, Llewelyn Newton. University College, Bristol.
1882. ‡*Tyer, Edward. Horneck,* 16 *Fitzjohn's-avenue, Hampstead, N.W.*
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S., Professor of Anthropology, and Keeper of the University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. §§Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.
1861. *Tysoe, John. Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.

Year of Election.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡*Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.*
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1898. §Usher, Thomas. 3 Elmgrove-road, Cotham, Bristol.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1896. ‡Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1886. ‡VARDY, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, N.
1865. *VARLEY, S. ALFRED. 5 Gayton-road, Hampstead, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, W.
1895. §Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1887. *VAUGHAN, His Eminence Cardinal. Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 22 Norham-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡VERNON, H. H., M.D. York-road, Birkdale, Southport.
1896. *Vernon, Thomas T. 24 Waterloo-road, Waterloo, Liverpool.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Lieut.-Colonel R. de, R.E. 55 Queensborough-terrace, W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian, Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. Leamington Spa.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, G. H. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Bank View, Chapel Allerton, Leeds.
1896. ‡Wailes, Miss Ellen. Woodmead, Groombridge, Sussex.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.

Year of Election.

1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡Walcot, John. 50 Northumberland-street, Edinburgh.
1884. ‡Waldstein, C., M.A., Ph.D. Slade Professor of Fine Art in the University of Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡WALFORD, EDWIN A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel. Downside, Whitchurch, Tavistock.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Nant-y-Glyn, Colwyn Bay.
1890. ‡Walker, A. Tannett. Hunslet, Leeds.
1897. *WALKER, B. E. Canadian Bank of Commerce, Toronto
1883. ‡Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. ‡Walker, Frederick W. Hunslet, Leeds.
1897.§§Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. ‡Walker, Horace. Belvidere-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡WALKER, J. J., M.A., F.R S. 12 Denning-road, Hampstead, N.W.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1895. §WALKER, WILLIAM G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall. Gateacre, Liverpool.
1896. ‡Walker, W. J. D. Lawrencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1897.§§Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston, Birmingham.
1894. *WALMISLEY, A. T., M.Inst.C.E. (LOCAL TREASURER). Engineer's Office, Dover Harbour.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1883. ‡*Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.*
1895.§§WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.

Year of
Election.

1887. ‡Ward, A. W., M.A., Litt.D.
1874. ‡*Ward, F. D., J.P., M.R.I.A. Wyncroft, Adelaide Park, Belfast.*
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, D.Sc., F.R.S., F.L.S., Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.
1887. ‡WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡*Ward, Thomas. Arnold House, Blackpool.*
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Standard Underground Cable Co., 16th-street, Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. High Bank, Harpenden, St. Albans, Herts.
1882. ‡Warner, F. I., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. ‡*Warr, A. F. 4 Livingstone-drive North, Liverpool.*
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1875. ‡Warren, Algernon. Downgate, Portishead.
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, S.W.
1898. §Warrington, Arthur W. University College, Aberystwith.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Lieut.-Colonel J. Oak Lodge, Court-road, Eltham, Kent.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. 34 Smallbrook-street, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, W.C.
1892. §Watson, G., Assoc.M.Inst.C.E. 21 Springfield-mount, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. P.O. Box 317, Johannesberg, South Africa.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1894. *WATSON, W., B.Sc. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones, Cumberland.
1882. ‡Watt, Alexander. 19 Brompton-avenue, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.

Year of
Election.

1884. *Watts, Rev. Canon Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near Penistone.
1896. ‡Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. *WATTS, W. W., M.A., Sec. G.S., Assistant Professor of Geology in the Mason Science College, Birmingham.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡Webb, Sidney. 4 Park-village East, N.W.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886.§§WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, E.C.
1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, S.W.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. 48 Westendstrasse, Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. *Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, S.W.
1894. §Weld, Miss. Conal More, Norham Gardens, Oxford.
1876. *WELDON, W. F. R., M.A., F.R.S., F.L.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, W.
1880. *Weldon, Mrs. 30A Wimpole-street, W.
1897.§§Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill Buildings, E.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894. ‡Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1898. §West, Charles D. Imperial University, Tokyo, Japan.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1897.§§Western, Alfred E. 36 Lancaster-gate, W.
1882. *Westlake, Ernest, F.G.S. Vale Lodge, Vale of Health, Hampstead, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.

Year of Election.

1882. ‡WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1885. *WHARTON, Admiral Sir W. J. L., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *WHETHAM, W. C. D., M.A. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, S.W.
1898. §Whipple, Robert S. Scientific Instrument Company, Cambridge.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Freda, Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. §Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1898. §White, George. Clare-street House, Bristol.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. 5 King-street, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡*White, John Forbes.* 311 *Union-street, Aberdeen.*
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. 6 Southwell-gardens, S.W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1898. §White, Samuel. Clare-street House, Bristol.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 66 Cambridge-gardens, Notting Hill, W.
1883. *White, Mrs. 66 Cambridge-gardens, Notting Hill, W.
1886. *White, William. The Ruskin Museum, Sheffield.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. The Admiralty, Whitehall, S.W.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 20 Beeches-road, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡Whitla, Valentine. Beneden, Belfast.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Headingley, Leeds.
1897. §Whittaker, E. T. Trinity College, Cambridge.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 11 Poplar-road, Ramsgate.
1887 ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.

Year of Election.

1874. *Whitwill, Mark. 1 Berkeley-square, Clifton, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1897. §§Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1896. ‡Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1883. ‡Wigglesworth, Mrs. 23 Westbourne-grove, Scarborough.
1881. **Wigglesworth, Robert. Beckwith Knowle, near Harrogate.*
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, F.R.S. The Hurst, Alderley Edge, Manchester.
1896. §§Wildermann, Meyer. 22 Park-crescent, Oxford.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1892. ‡Wilkinson, Rev. J. Frome., M.A. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Elmhurst Hall, Lichfield.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. Vale Bank, Knutsford, Cheshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1872. ‡WILLETT, HENRY. Arnold House, Brighton.
1894. ‡Willey, Arthur. New Museums, Cambridge.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1857. ‡Williams, Rev. James. Llanfairynghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entry Hill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Lingfield Grange, Branksome Park, Bournemouth.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke Vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡WILLIAMS, MATTHEW W. 26 Elizabeth-street, Liverpool.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. 28 Compayne-gardens, West Hampstead, London, N.W.
1883. ‡Williams, T. H. 21 Strand-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.

Year of Election.

1895. ‡WILLINK, W. 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., Senior Assistant in Botany in Glasgow University. 8i Lawrence-place, Dowanhill, Glasgow.
1896. §WILLISON, J. S. Toronto.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1898. §Wills, H. H. Barley Wood, Wrington, R.S.O., Somerset.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. The Athenæum Club, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1875. ‡WILSON, GEORGE FERGUSSON, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1895. ‡Wilson, Gregg. The University, Edinburgh.
1883. *Wilson, Henry, M.A. Farnborough, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1896. ‡Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.
1865. ‡WILSON, Ven. JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡*Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.*
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., Professor of Anatomy in Mason College, Birmingham.
1887. ‡*Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.*
1893. *Winter, G. K., M.Inst.C.E., F.R.A.S. C/o The Union Bank of London, 2 Princes-street, E.C.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, Right Hon. E. R., M.P. 56 Chester-square, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1898. §Wollaston, G. H. Clifton College, Bristol.
1884. ‡Womack, Frederick, M.A., B.Sc., Lecturer on Physics and Applied

Mathematics at St. Bartholomew's Hospital. Bedford College, Baker-street, W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. ‡Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, W.C.
1883. *WOOD, JAMES, LL.D. Grove House, Scarisbrick-street, Southport.
1881. ‡*Wood, John, B.A. Wharfedale College, Boston Spa, Yorkshire.*
1883. *Wood, J. H. Hazelwood, 14 Lethbridge-road, Southport.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *Wood, Rev. William Spicer, M.A., D.D. Waldington, Combe Park, Bath.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. 5 Queen's-mansions, Victoria-street, S.W.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, N.W.
1896. §Woodhead, G. Sims, M.D. 1 Nightingale-lane, Balham, S.W.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*WOODS, EDWARD, M.Inst.C.E. 8 Victoria-street, Westminster, S.W.
1883. ‡*Woods, Dr. G. A., F.R.S.E., F.R.M.S. 16 Adelaide-street, Leamington.*
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, S.W.
1887. *WOODWARD, ARTHUR SMITH, F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1894. *Woodward, John Harold. 6 Brighton-terrace, Merridale-road, Wolverhampton.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith. South Collingham, Newark.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. The Hill, Stourbridge

Year of Election.

1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, N.W.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Bastow.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. §§WRIGHT, Professor R. RAMSAY, M.A., B.Sc. University College, Toronto, Canada.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡WRIGHTSON, THOMAS, M.P., M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1898. §Wrong, Professor George M. The University, Toronto, Canada.
1897. §§Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1883. §Wyllie, Andrew. Sandown, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 23 Oakfield-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1883. §§Yates, James. Public Library, Leeds.
1896. ‡Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, S.W.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, S.E.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. Firth College, Sheffield.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1896. ‡Young, J. Denholm. 88 Canning-street, Liverpool.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S., Professor of Chemistry in University College, Bristol. 10 Windsor-terrace, Clifton, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of
Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States. (3909, Locust-street).
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. The University, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1894. Deputy Surgeon-General J. S. Billings. Washington, United States.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. IX. Fürkenstrasse 3, Vienna.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, United States.
1890. Professor Dr. L. Brentano. Maximilian-platz 1, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Kristiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale College, New Haven, Conn., United States.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, United States.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. Royal University of Bologna. (65 Via Zamboni).
1887. Professor J. B. Carnoy. Rue du Canal 22, Louvain.
1887. Hofrath Dr. H. Caro. Mannheim.
1894. Emile Cartailhac. 5 Rue de la Chaîne, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1894. Dr. A. Chauveau. The Sorbonne, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1873. Professor Guido Cora. Via Goito 2, Rome.
1880. Professor Cornu. Rue de Grenelle 9, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome. (5 Piazza S. Pietro in Vincoli).

Year of Election.

1889. W. H. Dall. United States Geological Survey, Washington, D.C., United States.
1872. Professor G. Dewalque. Liége, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 5 Quai Marcellis, Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Holland.
1892. Professor F. Elfving. Helsingfors, Finland.
1894. Professor T. W. W. Engelmann. N. Wilhelmstrasse 15, Berlin.
1892. Professor Léo Errera. 38 Rue de la Loi, Brussels.
1874. Dr. W. Feddersen. 9 Carolinenstrasse, Leipzig.
1886. Dr. Otto Finsch. Leiden, Netherlands.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1894. Professor Léon Fredericq. Rue de Pitteurs 18, Liége, Belgium.
1894. Professor C. Friedel. 9 Rue Michelet, Paris.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague.
1892. Professor Dr. Gustav Fritsch. Roon Strasse 10, Berlin.
1881. Professor C. M. Gariel. 6 Rue Edouard Detaille, Paris.
1866. Dr. Gaudry. 7 bis Rue des Saints Pères, Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale University, New Haven, Conn., United States.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, D.C., United States.
1892. Daniel C. Gilman. President of the Johns Hopkins University, Baltimore, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. l'Université, Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, D.C., U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. Rue de Drapiers 35, Brussels.
1894. Professor Ludimar Hermann. The University, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Museum, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Holland.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, Rhode Island, United States.
1884. Professor C. Loring Jackson. 12 Wave-street, Cambridge, Massachusetts, United States.
1867. Dr. J. Janssen, LL.D. L'Observatoire, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.

Year of Election.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. 32 East Preston-street, Baltimore, U.S.A.
1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 9 Via Borgo Nuovo, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.
1873. Professor Dr. Felix Klein. Wilhelm Weber Strasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 92, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor W. Krause. Knesebeckstrasse, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
1887. Professor J. W. Langley. 847½ Fairmount-street, Cleveland, Ohio, United States.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, United States.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, United States.
1872. M. Georges Lemoine. 76 Rue Notre Dame des Changes, Paris.
1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
1883. Dr. F. Lindemann. Georgenstrasse 42/0, Munich.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. Professor Dr. Georg Lunge. The University, Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg-in-Breisgau, Germany.
1871. Professor Dr. Lütken. Nörregade 10, Copenhagen, Denmark.
1894. Dr. Otto Maas. Wurzerstrasse 1b, Munich.
1887. Dr. Henry C. McCook. 3,700 Chestnut-street, Philadelphia, United States.
1867. Professor Mannheim. Rue de la Pompe 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, Conn., United States.
1887. Dr. C. A. Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
1887. Professor D. I. Mendeléeff, D.C.L. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1848. Professor J. Milne-Edwards. 57 Rue Cuvier, Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1894. Professor G. Mittag-Leffler. Djuvsholm, Stockholm.
1893. Professor H. Moissan. The Sorbonne, Paris (7 Rue Vauquelin).
1877. Professor V. L. Moissenet. 4 Boulevard Gambetta, Chaumont, Hte. Marne, France.
1894. Dr. Edmund von Mojsisovics. III/3. Strohgasse 26, Vienna.
1897. Professor Oskar Montelius. Stockholm, Sweden.
1897. Professor E. W. Morley. Cleveland, Ohio, U.S.A.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.

Year of
Election.
1889. Dr. F. Nansen. Lysakr, Norway.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padua, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. 1620 P.-street, Washington, D.C., United States.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Linnestrasse 2/8, Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, United States.
1890. Maffeo Pantaleoni. Geneva.
1895. Professor F. Paschen. Nelkenstrasse 14, Hannover.
1887. Dr. Pauli. Füldbergstrasse 49, Frankfurt a. M., Germany.
1890. Professor Otto Pettersson. Hogskolas Laboratorium, Stockholm.
1894. Professor W. Pfeffer, D.C.L. The University, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, D.C., United States.
1886. Professor Putnam. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor Georg Quincke. Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich (Sonnenstrasse 7).
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1886. Rev. A. Renard. 6 Rue du Roger, Gand, Belgium.
1897. Professor Dr. C. Richet. Faculté de Médecine, Paris, France.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin.
1896. Dr. van Rijckevorsel. Parklaan 7, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, United States.
1881. Professor Henry A. Rowland. Baltimore, United States.
1895. Professsr Karl Runge. Körnerstrasse 19A, Hannover.
1894. Professor P. H. Schoute. The University, Groningen, Holland.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1883. Dr. Ernst Schröder. Gottesanerstrasse 9, Karlsruhe in Baden.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1873. Dr. A. Shafarik. Weinberge, Kopernicus Gasse 422, Prague.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands. Utrecht.
1887. Professor Count Solms. Bot. Garten, Strassburg.
1887. Ernest Solvay. 25 Rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. Box 621, Cincinnati, Ohio, United States.
1889. Professor G. Stefanescu. Stradaverde 8, Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. The University, Breslau.
1884. Professor Robert H. Thurston. Sibley College, Cornell University, Ithaca, New York, United States.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, United States.

Year of
Election.

Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor Dr. J. H. van't Hoff. Uhlandstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1886. Professor Jules Vuylsteke. 59 Rue du Congres, Brussels, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Kiel.
1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, United States.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1887. Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]
1874. Professor G. Wiedemann. Thalstrasse 35, Leipzig.
1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Professor Dr. J. Wislicenus. Liebigstrasse 18, Leipzig.
1887. Dr. Otto N. Witt. 21 Siegmundshof, Berlin, N.W. 23.
1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887. Professor C. A. Young. Princeton College, New Jersey, U.S.A.
1896. Professor E. Zacharias. Botanischer Garten, Hamburg.
1887. Professor F. Zirkel. Thalstrasse 33, Leipzig.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Belfast, Queen's College.
Birmingham, Midland Institute.
Brighton Public Library.
Bristol Naturalists' Society.
Cambridge Philosophical Society.
Cardiff, University College.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Institute of Science.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library.
——, Royal Institution.
London, Admiralty, Library of the.
——, Anthropological Institute.
——, Arts, Society of.
——, Chemical Society.
——, Civil Engineers, Institution of.
——, East India Library.
——, Geological Society.
——, Geology, Museum of Practical, 28 Jermyn Street.
——, Greenwich, Royal Observatory.
——, Guildhall, Library.
——, Kew Observatory.
——, King's College.
——, Linnean Society.
London, London Institution.
——, Mechanical Engineers, Institution of.
——, Meteorological Office.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Engineers' Institute, Chatham.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Society.
——, Royal Statistical Society.
——, Sanitary Institute.
——, United Service Institution.
——, University College.
——, War Office, Library.
——, Zoological Society.
Manchester Literary and Philosophical Society.
——, Mechanics' Institute.
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
——, Biological Association.
Salford, Royal Museum and Library.
Sheffield, University College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Swansea, Royal Institution of South Wales.
Yorkshire Philosophical Society.
The Corresponding Societies (see list in Report).

EUROPE.

Berlin	Die Kaiserliche Akademie der Wissenschaften.
Bonn	University Library.
Brussels	Royal Academy of Sciences.
Charkow	University Library.
Coimbra	Meteorological Observatory.
Copenhagen	Royal Society of Sciences.
Dorpat, Russia	University Library.
Dresden	Royal Museum.
Frankfort	Natural History Society.
Geneva	Natural History Society.
Göttingen	University Library.
Grätz	Naturwissenschaftlicher Verein.
Halle	Leopoldinisch-Carolinische Akademie.
Harlem	Société Hollandaise des Sciences.
Heidelberg	University Library.
Helsingfors	University Library.
Jena	University Library.
Kazan, Russia	University Library.
Kiel	Royal Observatory.
Kiev	University Library.
Lausanne	The University.
Leyden	University Library.
Liège	University Library.
Lisbon	Academia Real des Sciences.
Milan	The Institute.
Modena	Royal Academy.
Moscow	Society of Naturalists.
——	University Library.
Munich	University Library.
Naples	Royal Academy of Sciences.
Nicolaieff	University Library.
Paris	Association Française pour l'Avancement des Sciences.
——	Geographical Society.
——	Geological Society.
——	Royal Academy of Sciences.
——	School of Mines.
Pultova	Imperial Observatory.
Rome	Accademia dei Lincei.
——	Collegio Romano.
——	Italian Geographical Society.
——	Italian Society of Sciences.
St. Petersburg	University Library.
——	Imperial Observatory.
Stockholm	Royal Academy.
Turin	Royal Academy of Sciences.
Utrecht	University Library.
Vienna	The Imperial Library.
——	Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich	General Swiss Society.

ASIA.

Agra	The College.
Bombay	Elphinstone Institution.
——	Grant Medical College.
Calcutta	Asiatic Society.
Calcutta	Hooghly College.
——	Medical College.
——	Presidency College.
Ceylon	The Museum, Colombo.
Madras	The Observatory.
——	University Library.

AFRICA.

Cape of Good Hope	The Royal Observatory.

AMERICA.

Albany	The Institute.
Boston	American Academy of Arts and Sciences.
California	The University.
——	Lick Observatory.
Cambridge	Harvard University Library.
Chicago	American Medical Association.
——	Field Columbian Museum.
Kingston	Queen's University.
Manitoba	Historical and Scientific Society.
Mexico	Sociedad Cientifica 'Antonio Alzate.'
Montreal	Council of Arts and Manufactures.
——	McGill University.
New York	American Society of Civil Engineers.
——	Lyceum of Natural History.
Ottawa	Geological Survey of Canada.
Philadelphia	American Philosophical Society.
——	Franklin Institute.
Toronto	The Observatory.
——	The University.
Washington	Bureau of Ethnology.
——	Smithsonian Institution.
——	The Naval Observatory.
——	United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide	The Colonial Government.
Brisbane	Queensland Museum.
Sydney	Public Works Department.
Victoria	The Colonial Government.

NEW ZEALAND.

Canterbury Museum.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
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